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Construction Engineering
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Heating, Ventilating, and Air-Conditioning Controls Operations and Maintenance Field Manual

David M. Schwenk and Richard L. Strohl

February 2001

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Foreword

This study was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE) under project number 622784AT45, "Energy Technologies applied to Military Facilities"; Work Unit X40, "Effective Maintenance of HVAC Facilities." The technical monitors were John Lanzarone and Joe McCarty, CEMP-ET.

Special credit is due to the many mechanics who have shared their insight, knowledge and many years of experience in the preparation of this manual, including: Phil Connor and Gratz Buck (Fort Campbell), Roger Chism (Fort Campbell), Darrel Cimbanin (Fort Hood), Dennis Ewert (Fort Riley), Earl Hollis (Fort Campbell), John Holmes (Fort Hood), George Kline (Fort Campbell), Eric Ricker (Fort Myer), Warren Speight (Fort Myer), Bobby Taylor (Fort Hood), Jerry Wright (Fort Riley), and others. Additionally, student researchers Jennifer Barnard and Gary (J.R.) Muse provided significant contributions towards the development of the illustrations, tables, and appendices in this manual.

The work was performed by the Energy Branch (CF-E) of the Facility Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL Principal Investigators were David M. Schwenk and Richard L. Strohl. The technical editor was William J. Wolfe, Information Technology Laboratory. Larry Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary Schanche. The Acting Director of CERL is Dr. Alan W. Moore..

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1 Introduction

Background

Complex and varied technologies make the operation and maintenance (O&M) of heating, ventilating, and air-conditioning (HVAC) control systems very challenging. To simplify the design, construction, and O&M of HVAC controls, the U.S. Army Corps of Engineers has developed standardized control system designs and hardware. Adherence to the standards benefits those individuals who perform O&M routines because standardization increases the similarity of systems, reduces the stock of replacement parts, and allows mechanics to adapt to a uniform method for correcting performance problems. The O&M material in this manual is based on these standard systems. This manual describes how to interpret HVAC control system documentation, how to break the system down into control loops, and how to use that information to help troubleshoot and correct operational problems.

Additional technical assistance is available from the Technical Center of Expertise (TCX) for HVAC controls at U.S. Army Engineering District, Savannah, P.O. Box 889, Savannah, GA 31402-0889; tel. (912) 652-5386.

Objective

The objective of this work was to compose a reference manual to help the HVAC mechanic perform routine O&M on U.S Army Corps of Engineers "standard" HVAC control systems.

Approach

Where needed, sections will cross-reference to other sections or appendices to guide the reader to related data. Examples may be used to illustrate how to interpret design documents such as the sequence-of-operation, control diagram, electrical ladder diagram, and equipment schedule.

Using posted instructions, describes and explains how to interpret HVAC control system documentation that describes system operation. Interpreting posted instructions is a skill that is fundamental to understanding this manual.

Control panel operation describes how to operate the standard control panel and includes a description of the control panel devices, push buttons, pilot lights, and gages.

Troubleshooting chapters describe HVAC systems, loops, and hardware and provides troubleshooting information. Systems and loops are described using typical posted instructions. Control settings and adjustments are described along with specific guidance on troubleshooting techniques to aid in identifying and correcting HVAC control problems.

O&M mechanics role beyond O&M provides information that is critical to new construction. It will explain the mechanics role in providing input that will help throughout the design/construction process to improve the HVAC systems in new and rehabilitated facilities.

Glossary of terms, describes single-loop digital controller terminology.

Appendixes contain typical setpoints and controller PID values, conversion tables, and a list symbols and acronyms.

Scope

This manual is not meant to eliminate the need for training. Mechanics should seek and be afforded training opportunities. Also, note that controls contractors are required to provide training on the systems they install. A 1-week Corps of Engineers sponsored HVAC Controls O&M training course based on the standard control systems is available by contacting the USACE Professional Development Support Center at (256) 895-7455.

Mode of Technology Transfer

It is anticipated that this manual will be used as a part of the Corps of Engineers sponsored HVAC Controls O&M training course based on the standard control systems. This manual will also be made available for public download via the world-wide web (WWW) at URL:

www.cecer.army.mil

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units, and accompanying equations are provided below.

Conversion Factors

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 cfm	=	0.472 L/s
1 gal	=	3.78 L
1 gal	=	0.0159 hogsheads
1 gpm	=	0.631 L/s
1 lb	=	0.453 kg
1 kip	=	453 kg
1 psi	=	6.895 kPa
1 iwc	=	2.49 Pa
°F	=	(°C x 1.8) + 32

Conversion Equations

Temperature Control:
deg F = (deg C x 1.8) + 32
deg C = 0.555 x (deg F - 32)

Airflow Control:
cfm = liters per second x 2.12
liters per second = cfm x 0.4719474

Water Flow Control:
gpm = Liters per second x 0.631
liters per second = gpm x 15.85

Pressure Control:
iwc = Pascals x 0.004
Pascals = iwc x 249.1
kPa = psi x 6.895
psi = kPa x 0.1450

Other:
psi = feet of head x 0.434
feet of head = psi x 2.3
inches = hands x 4
gallons = hogsheads x 63
gallons = liters x 0.265

Notation:
iwc = inches of water column
kPa = kiloPascals

2 Using Posted Instructions

Introduction

Posted Instructions, as defined in the Corps of Engineers *HVAC Control Systems* Guide Specification (CEGS-15950), describe the control system and the control panel. Understanding the Posted Instructions is critical to proper system operation and maintenance. Posted instructions should be provided by the contractor and consist of a set of Laminated Drawings, Panel Instructions, and a set of Operation and Maintenance Manuals. This chapter describes how to read and interpret posted drawings.

Posted drawings are half-size (11 x 17-on.) drawings laminated in plastic. Ordinarily the contractor "posts" these by bolting them to the mechanical room wall. The drawings should include:

- explanation of symbols and abbreviations
- control system schematic
- equipment schedule
- ladder diagram
- sequence of control
- control panel arrangement drawings
- wiring diagram
- valve and damper schedules.

Symbols and Abbreviations

The *Symbols and Abbreviations* drawing shows all symbols, equipment identifiers, and abbreviations used in the control drawings. A complete set of symbols and abbreviations are contained in the Glossary to this manual. Symbols and identifiers are used to identify control hardware. A circle, also referred to as a bubble, is the most common symbol used in the control drawings. As shown in Figure 1, a bubble with a horizontal line through it represents a control device located inside a control panel (a panel-mounted device). A bubble without a line through it represents a control device located external to a control panel (a field-mounted device).

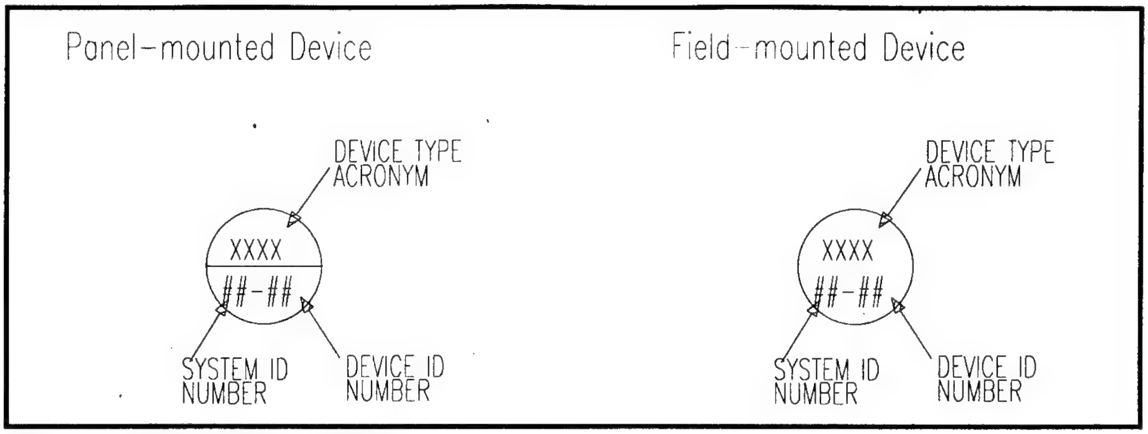


Figure 1. Control device symbols.

The identifier for each bubble consists of two parts that identify the device. The upper half of the bubble symbol shows the abbreviation of the device, and the lower half shows the system and device number. The upper half is limited to four letters and the lower half to four numbers. This is illustrated in Figure 1. An example of a field-mounted device is an airflow measurement array (AFMA), which might be designated AFMA-0201. This "AFMA" is located in system number "02" and is AFMA device number "01."

Symbols and identifiers are also used to identify HVAC equipment and are also shown in the Glossary. The basic shape is a hexagon with a bisecting line as shown in Figure 2. The upper half of the hexagonal contains up to four letters to abbreviate the device. Example equipment identifiers include; "EF" for an exhaust fan and "FLTR" for a filter.

Control Schematic

The *Control Schematic* is a functional diagram that shows the basic layout of the HVAC system controls. The control schematic also includes an equipment schedule and in some cases a sequencing chart. Figure 3 shows a typical control schematic for a heating and ventilating control system. Main (pneumatic) air source indicated by an M. Both main air and pneumatic control signal lines are represented by solid lines with double slashes. Electronic control signal lines appear as dashed lines.

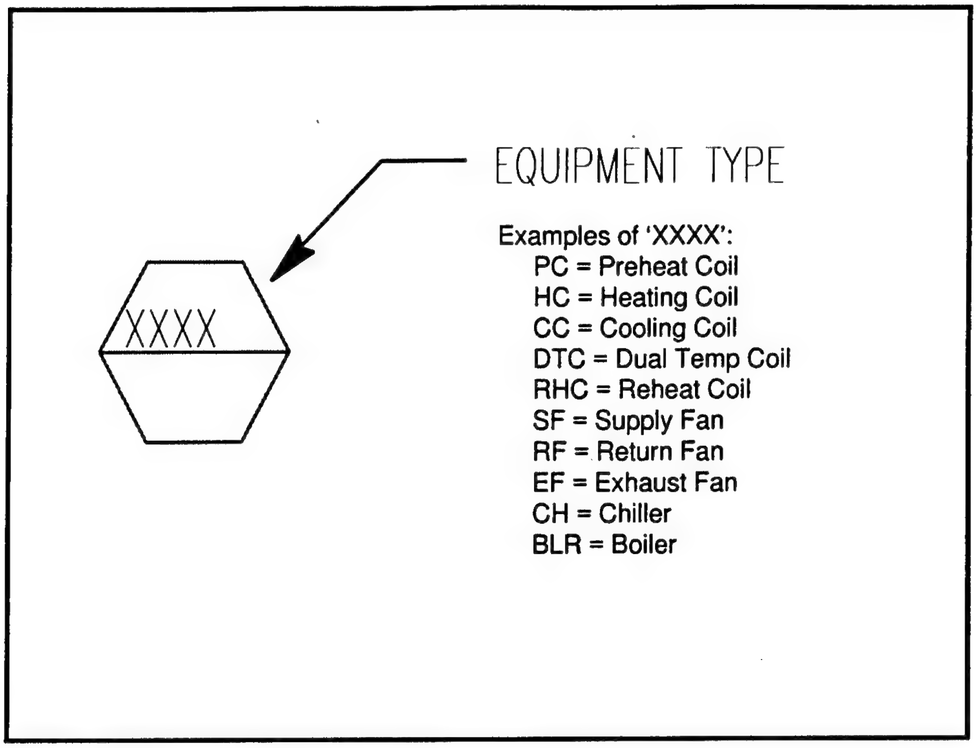


Figure 2. Equipment symbol.

Sequencing Schedules

Sequencing schedules (Figure 4) illustrate the relationship between the process variable (temperature, pressure, flow, relative humidity) and the positions of the controlled devices when the control system is in the occupied mode. Information provided in the sequencing schedule includes the relationship between the Process Variable (PV) space temperature (°F sensed by controller TC XX-01), the controller output signal in milliamps, and the current to pneumatic transducer (IP XX-01 and IP XX-02) output signals in units of pounds per square inch.

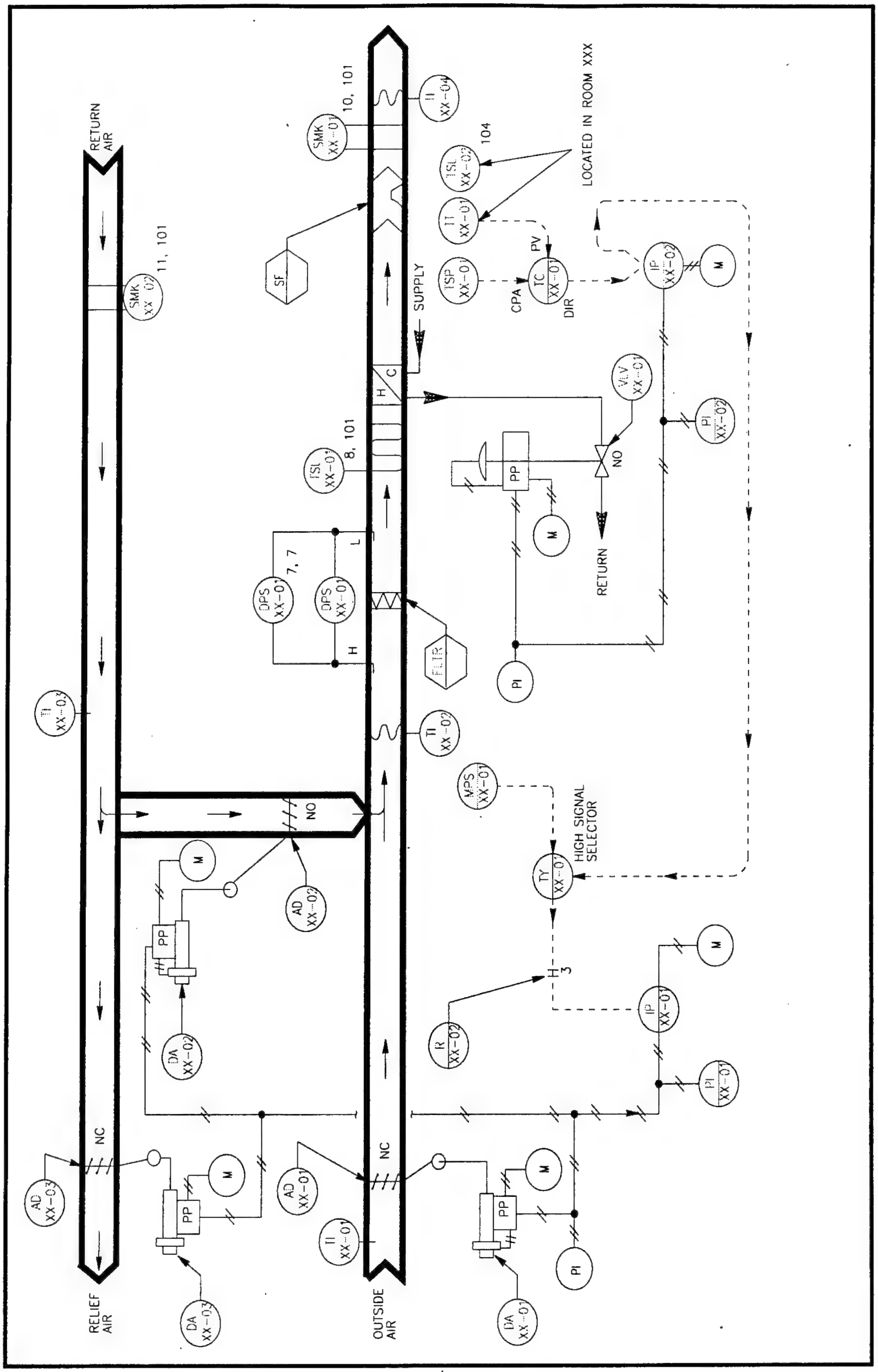


Figure 3. Typical control schematic.

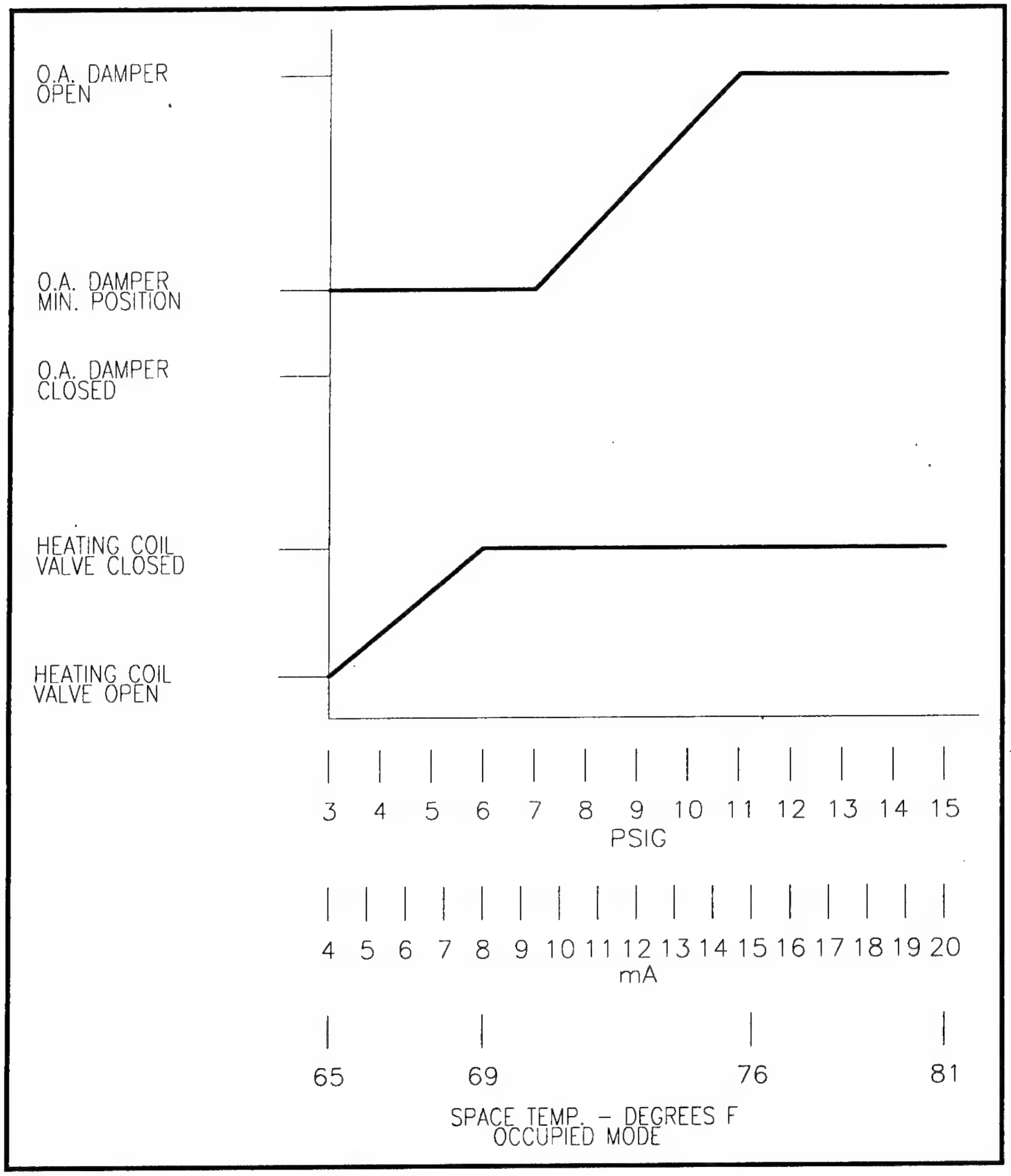


Figure 4. Typical sequencing schedule.

Equipment Schedule

The *Equipment Schedule* in Figure 5 lists each control device for each control loop found with-in an HVAC system. Important operational parameters for each device are shown, including; setpoint, device range, and additional parameters as may be required by the application. These parameters are selected by the designer and should be set-up initially during installation and commissioning of the control system.

Ladder Diagram

The _Ladder Diagram_ is used to show the operating sequence and control modes of the various control devices, safeties, and interlocks. The example ladder diagrams shown in Figures 6 and 7 are for a heating and ventilating control system. The ladder diagram in Figure 6 describes the control logic within the system control panel. The ladder diagram in Figure 7 shows the logic of the supply fan starter circuit. Ladder diagrams are read from top to bottom and left to right. Each line, or "rung" of the ladder diagram has a reference number. The first rung (labeled 0) provides power to the time clock (CLK). Note that the bubble for the clock has a bisecting line through it, which indicates that it is located in the control panel.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
SPACE TEMPERATURE	DA-XX-01 DA-XX-02 DA-XX-03	DAMPER ACTUATOR	—	7-11 PSIG	—
	MPS-XX-01	MINIMUM POSITION SWITCH	—	—	SET MINIMUM OA CFM EQUAL TO XXXX CFM
	TSL-XX-01	FREEZESTAT	35 DEG F	—	—
	VLV-XX-01	HEATING COIL VALVE	—	3-6 PSIG	Cv = _ CLOSE AGAINST _ PSIG
	TC-XX-01	SPACE TEMPERATURE CONTROLLER	—	50 TO 85 DEG F	SET LIMITS AVAILABLE TO OCCUPANT BY TSP-XX-01 AT 66 - 72 DEG F
	TT-XX-01	SPACE TEMPERATURE TRANSMITTER	—	50 TO 85 DEG F	—
	TSP-XX-01	REMOTE SETPOINT ADJUSTMENT	4 mA = 50 DEG F 20 mA = 85 DEG F	—	—
SPACE LOW TEMPERATURE	TSL-XX-02	NIGHT STAT - SPACE LOW TEMPERATURE PROTECTION	55 DEG F	5 DEG F DIFFERENTIAL	—
OCCUPIED MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE CLOSED: 0705 HRS, OPEN: 1700 HRS M,T,W,TH,F	OPEN: SAT, SUN AND HOLIDAYS
VENTILATION DELAY MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE CLOSED: 0700 HRS, OPEN: 0800 HRS M,T,W,TH,F	

NOTE: OTHER CONTROL DEVICES SUCH AS i/Ps, RELAYS, SIGNAL SELECTERS AND TERMINAL UNIT CONTROLLERS ARE NOT SHOWN.

Figure 5. Typical equipment schedule.

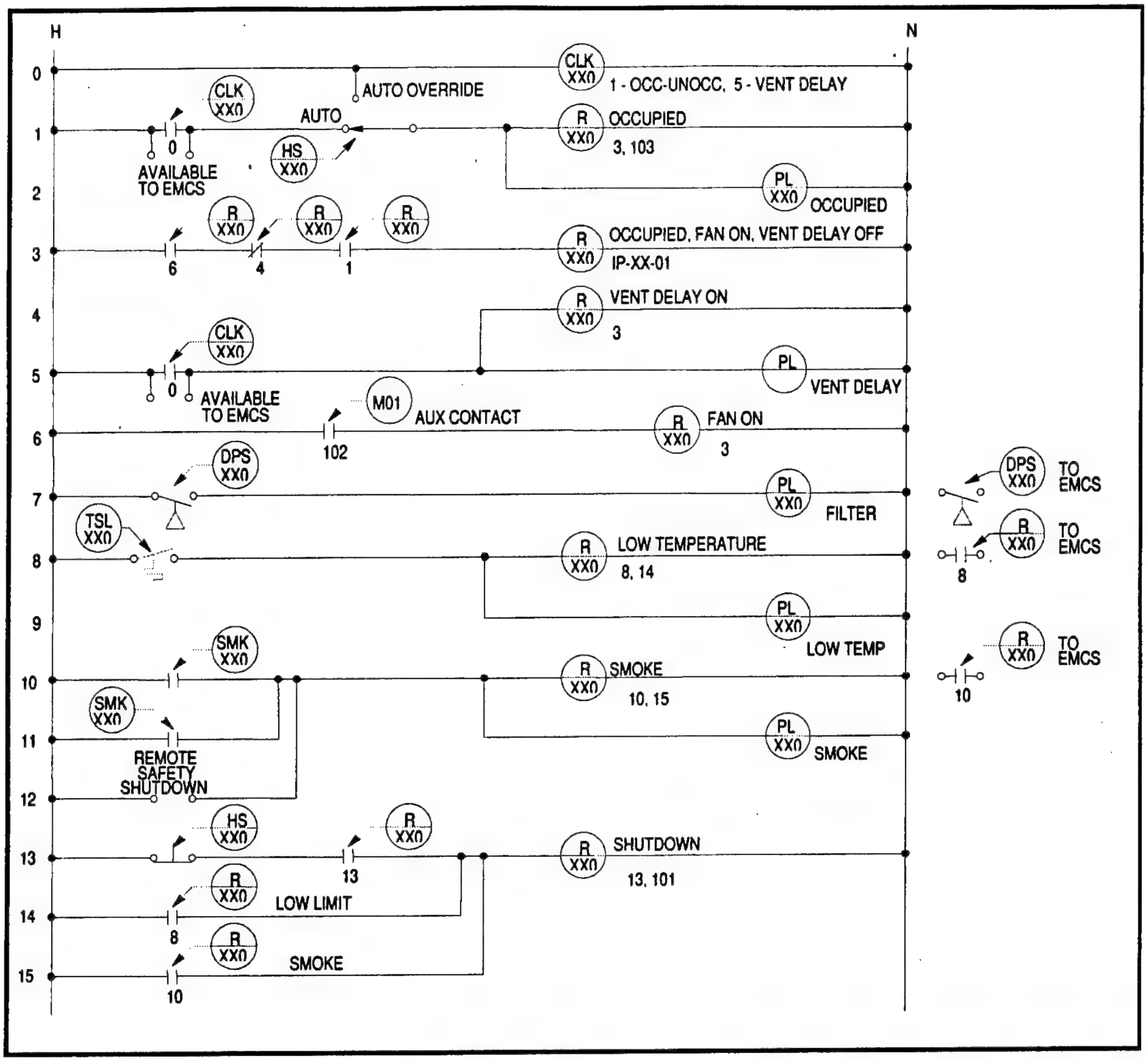


Figure 6. Typical ladder diagram for HVAC control panel.

Each device on the ladder diagram may also refer to devices located on other rungs and control functions. Look at CLK on line 0. Note the references to 1 (rung 1 on the ladder diagram) and Occ-Unocc and rung 5 Vent Delay. On line 1 we see the Normally Open contact of CLK, which refers back to line 0. This contact controls the occupied and unoccupied modes of the control systems when hand switch HS is in the auto position. When this rung is powered it energizes relay R-XX01 and pilot light PL-XX01on rung 2. R-XX01 refers to occupied to inform the reader that it is associated with the occupied control mode and also refers to rungs 3 and 103.

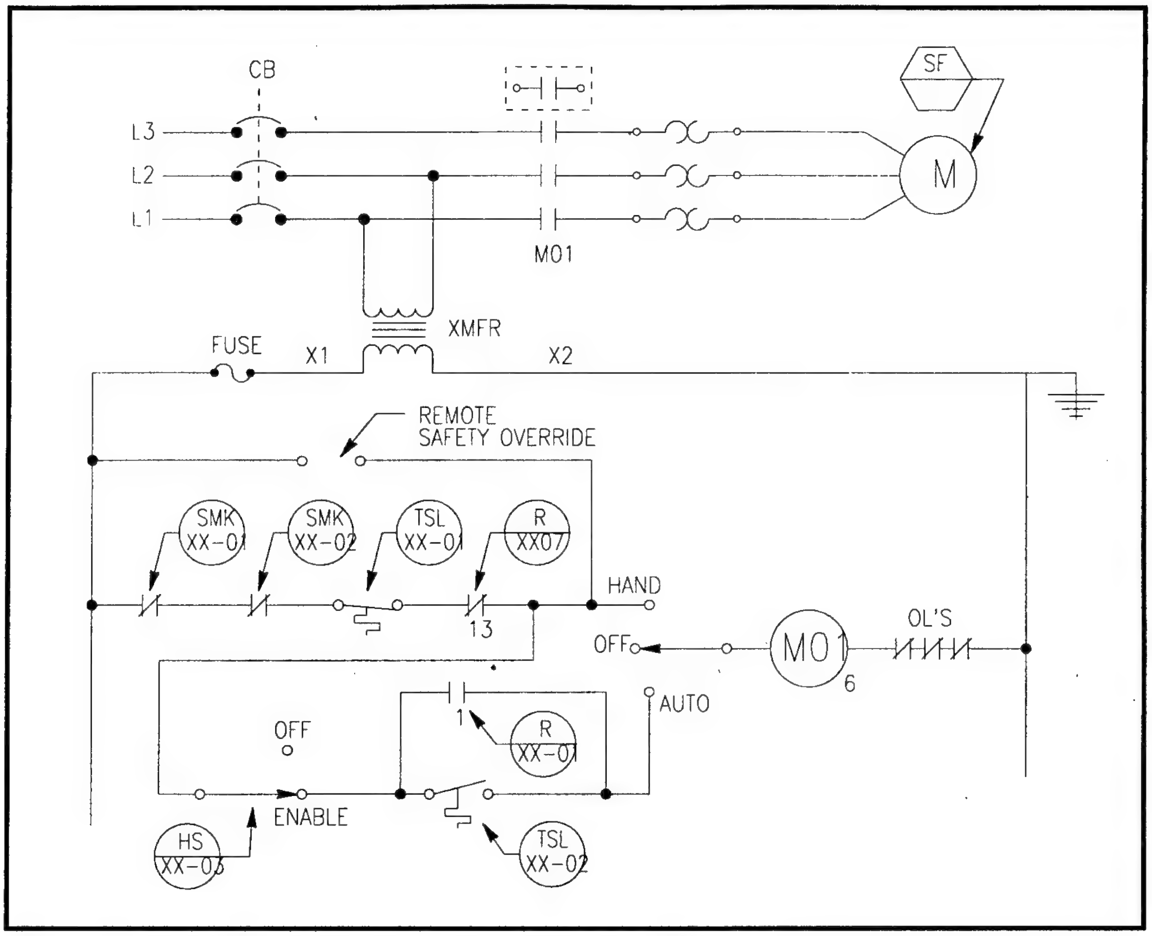


Figure 7. Typical ladder diagram for control system fan starter circuit.

On rung 3 there are 4 relays; R-XX04 (NO) cross referenced to rung 6, R-XX03 (NC) referencing rung 4, R-XX01 (NO) referencing rung 1, and R-XX02 referencing occupied, fan on, vent delay off, and IP-XX01. When the fan is on, the fan motor starters closes a NO contact on rung 6, energizing R-XX04. When R-XX04 is energized, the NO contact on rung 3 closes. When the vent delay mode ends, the CLK NO contact on rung 5 opens, PL XX02 is off and R XX03 is not powered causing the NC contacts of R XX03 to close on rung 3. R XX01 NO contact is closed by CLK on rung 1. When all three relay contacts are closed on this rung, R XX02 is energized. R XX02 is referenced to IP XX01 on the controls schematic. Locate IP XX01 and R XX02 on the control schematic (Figure 3). R XX02 has to be energized to close the NO contact, which completes the control signal circuit from TY XX01 to IP XX01. Note that R XX02 refers back to rung 3.

The ladder diagram provides needed information that illustrates the logic, or sequence of control that must occur for various parts of the control system to operate. When a control device is not functioning properly (does not turn on or off) follow the sequence and check all components.

Sequence of Operation

The *Sequence of Operation* is a written description of the HVAC control system operating modes and control functions. It is intended to provide a clear and accurate description of the sequential relationship between the control schematic and the ladder diagram.

An example sequence of operation for a "heating and ventilating system" would follow this order:

1. Time clock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-03 and turning on pilot light PL-XX-02. The normally closed contacts of relay R-XX-03 open to prevent relay R-XX-02 from being energized. The normally open contacts of relay R-XX-02 prevent signals from reaching current-to-pneumatic transducer IP-XX-01. The dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.
2. When the occupied contacts of time clock CLK-XX-01 close, relay R-XX-01 is energized and pilot light PL-XX-01 is turned on. Contacts of relay R-XX-01 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-04.
3. When the ventilation delay contacts of time clock CLK-XX-01 open to end the ventilation delay mode, relay R-XX-03 is de-energized and pilot light PL-XX-02 is turned off. With the now closed (but normally open) contacts of energized relays R-XX-01 and R-XX-04, the normally closed contacts of relay R-XX-03 energize relay R-XX-02. The normally open contacts of relay R-XX-02 connect the output signal of high signal selector TY-XX-01 to current-to-pneumatic transducer IP-XX-01. The pneumatic output of transducer IP-XX-01 places the dampers at the minimum position set on minimum position switch MPS-XX-01 or under control of space temperature controller TC-XX-01, whichever signal is higher.
4. Temperature controller TC-XX-01, with its temperature transmitter in the space served, through current-to-pneumatic transducer IP-XX-02, modulates heating coil valve VLV-XX-01, and during the occupied mode after the expiration of the ventilation delay mode, modulates the control dampers in sequence with the heating coil valve to maintain the temperature controller setpoint.
5. On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. Through its open contacts, thermostat TSL-XX-01 energizes relay R-XX-05 and lights pilot light PL-XX-04. The contacts of relay R-XX-05 energize relay R-XX-07. The normally closed contacts of relay R-XX-07 de-energize the supply fan, the normally open contacts lock in relay R-XX-07. To restart the

fan after a low temperature shutdown, both the low temperature protection thermostat TSL-XX-01 and the control panel must be reset. The control panel is reset by depressing manual switch HS-XX-02.

6. Whenever smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan start circuit open, de-energizing the fan. The normally open contacts close, energizing relay R-XX-06 and lighting pilot light PL-XX-05. Normally open contacts of relay R-XX-06 close, energizing relay R-XX-07. Normally closed contacts of relay R-XX-07 in the supply fan start circuit open, and the normally open contacts close to lock in relay R-XX-07. To restart the fan after a smoke shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be reset. The control panel is reset by depressing manual switch HS-XX-02.
7. Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-03.
8. At the conclusion of the occupied mode, the occupied contacts of time clock CLK-XX-01 open, and relay R-XX-01 is de-energized. The contacts of relay R-XX-01 open, de-energizing the supply fan and placing it under the control of the night thermostat TSL-XX-02.

Other Posted Instructions

The *Control Panel Arrangement Drawings*, *Wiring Diagrams*, and *Valve and Damper Schedules* are the remaining posted instructions (drawings). Control panel arrangement (layout) drawings and wiring diagrams are described later in this manual.

3 Control Panel Operation

Introduction

A standard control panel usually consists of a NEMA 12 enclosure 24 in. wide by 30 in. high by 16 in. deep. The inner door of the panel (Figure 8) contains single-loop digital controllers, push buttons (or hand switches) and pilot lights across the top of the inner door, and the panel-mounted pressure gages. This chapter describes the function and operation of each of these.

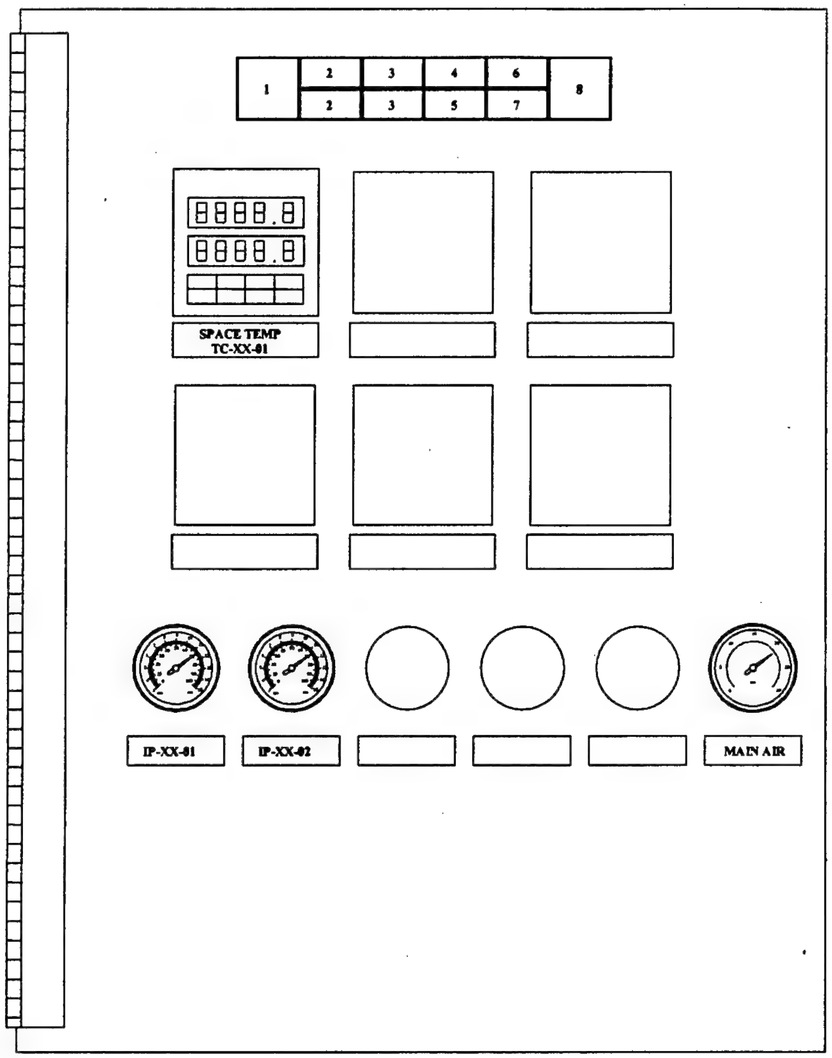
To assist in operation and maintenance of the control panel, the contractor should have supplied a set of Posted Instructions (described in Chapter 2 of this manual), Panel Instructions, and a set of Operation and Maintenance Manuals. These should include:

- control system drawings, including
  - list of symbols
  - sequence of operation
  - control schematic (including equipment schedule)
  - ladder diagram
  - wiring diagram
  - value, damper, schedule
- commissioning, instructions
- controller operators manual
- controller configuration check sheets
- time clock manual
- time clock configuration check sheet
- routine maintenance checklist.

Controller Operation

There are one to six controllers in a panel depending on the type of HVAC system being controlled (Figure 8). The upper display of the controller shows the process variable (temperature, pressure, humidity or flow). The lower display ordinarily will show the control setpoint. The controller will have LEDs or lights to show alarm relay contact closures, automatic or manual control mode, and remote or local setpoint mode. Other operating parameters, such as the controller

output signal and configuration parameter settings can be displayed by pushing the appropriate buttons on the front of the controller. Operation of the controller is described in detail in the contractor supplied Controller Operation Manual.



SWITCH AND PILOT LIGHT LEGEND

POSITION LEGEND	DEVICE TYPE	IDENTIFIER
1 - RESET	MOMENTARY	HS-XX-02
2 - AUTO/AUTO OVERRIDE	SWITCH (WITH LIGHT)	HS-XX-01
3 - ENABLE/OFF	SWITCH (WITH LIGHT)	HS-XX-03
4 - LOW TEMP	PILOT LIGHT	PL-XX-04
5 - SMOKE	PILOT LIGHT	PL-XX-05
6 - OCCUPIED	PILOT LIGHT	PL-XX-01
7 - VENT DELAY	PILOT LIGHT	PL-XX-02
8 - FILTER	PILOT LIGHT	PL-XX-03

Figure 8. Standard control panel (inner door).

Push Button and Pilot Light Operation

The push buttons and pilot lights described here are specific to the Heating and Ventilating Control System, but the majority of these push buttons and pilot lights are used in an identical manner in all the standard control panels. The legend at the bottom of Figure 8 lists the push buttons and pilot lights. These include:

1. **Reset button.** Used to turn the system fan back on following a low temperature (freezestat) alarm or smoke alarm. It is indicated as hand switch (HS XX-02) on line 13 of the ladder diagram in Figure 6.
2. **Auto/Auto Override.** When Auto half of the switch is pushed the OCC/UNOCC control modes (fan) are under control of the time clock. When the Auto Override half of the switch is pushed, the fan is forced on manually. Whenever the fan is on, the control panel is in "occupied" mode. The Auto/Auto Override switch is shown as hand switch (HS XX-01) on line 1 of the ladder diagram in Figure 6.
3. **Enable/Off.** When "enable" is pushed, the control system (hardware) has been enabled, or permitted, to energize the fan motor starter. When "Off" is pushed the fan cannot be started by the control system. In the Off position, the fan will start only in the HAND mode from the H-O-A switch. The Enable/Off switch is shown as hand switch (HS XX-03) on line 104 of the ladder diagram in Figure 7
4. **Low Temp** This pilot light indicates when there is a low temperature condition in the duct (when the freezestat {TSL} trips). The pilot light is turned off by pressing the manual reset button on the freezestat (TSL) then pushing the control panel *Reset Button* (described above). This pilot light is shown on line 9 of the ladder diagram in Figure 6.
5. **Smoke.** This pilot light indicates when the smoke detector (SMK) contact closes. The pilot light is turned off by removing the alarm condition at the fire alarm panel then pushing the control panel *Reset Button* (described above). This pilot light is shown on line 11 of the ladder diagram in Figure 6.
6. **Occupied.** This pilot light indicates when the control system is in the Occupied (OCC) mode. This occurs whenever the time clock (CLK) occupied contact closes or when the *Auto Override* button is pushed (described above). This pilot light is shown on line 2 of the ladder diagram in Figure 6.
7. **Filter.** This pilot light indicates when the differential pressure switch (DPS), installed across the air filter (FLTR), detects a large pressure drop (usually about 1 iwc) indicating a dirty filter. The pilot light is turned off by replacing the dirty filter. This pilot light is shown on line 7 of the ladder diagram in Figure 6.
8. **Vent Delay.** This pilot light indicates when the Time Clock (CLK) is in the ventilation delay mode. This occurs at the beginning of the occupied mode <u>and</u> the fan is on. The outside and relief air dampers remain closed, allowing the fan to circulate building air through the return duct, until the ventilation delay mode

ends and the CLK contact opens. This pilot light is shown on line 5 of the ladder diagram in Figure 6.

Pressure Gage Operation

Panel-mounted pressure gages are used to indicate the pneumatic pressure signal sent to the actuated control devices. The typical pressure range is 3 to 15 psi. When the digital controller output is 0 percent, its corresponding pressure gage should show 3 psi. When the digital controller output is 100 percent, its corresponding pressure gage should show 15 psi. There should be accompanying field mounted gages at each pneumatic actuator. The pressure gage located farthest to the right, on the control panel, is the main air pressure gage and should always indicate a pressure within a range of 18 to 25 psi.

Inside the Control Panel

Figure 9 shows the back of the inside of the control panel. The panel includes control relays that perform control logic and three rows of terminal blocks for wiring connections. Along the bottom of the panel are various components including:

- **Time Clock** (CLK-XX-01) controls OCCUPIED/UNOCCUPIED and VENT DELAY modes. The clock is interlocked with the AUTO/AUTO OVERRIDE switch as described in the *Push buttons and pilot lights* section. The clock time settings are shown in the Equipment Schedule drawing. Adjustment of the time settings will require use of the vendors time clock manual.
- **High Signal Selector** (TY XX-01) signal is connected to the AHU dampers. The function of this device is described in the Mixed Air Temperature control loop section of this manual. The high signal selector does not require adjustment.
- **Minimum Position Switch** (MPS XX-01) has a manual knob or screw adjustment to position the outside air damper for minimum fresh ventilation air. It is set by the contractor during commissioning and ordinarily should not be re-adjusted.
- **DC Power Supply** provides 24 V DC power to the field sensors/ transmitters.
- **Duplex Receptacle** serves as a 120V AC power outlet.
- **Fuse Block** for 120V AC power to the control panel.
- **Surge Protector** for 120V AC power.

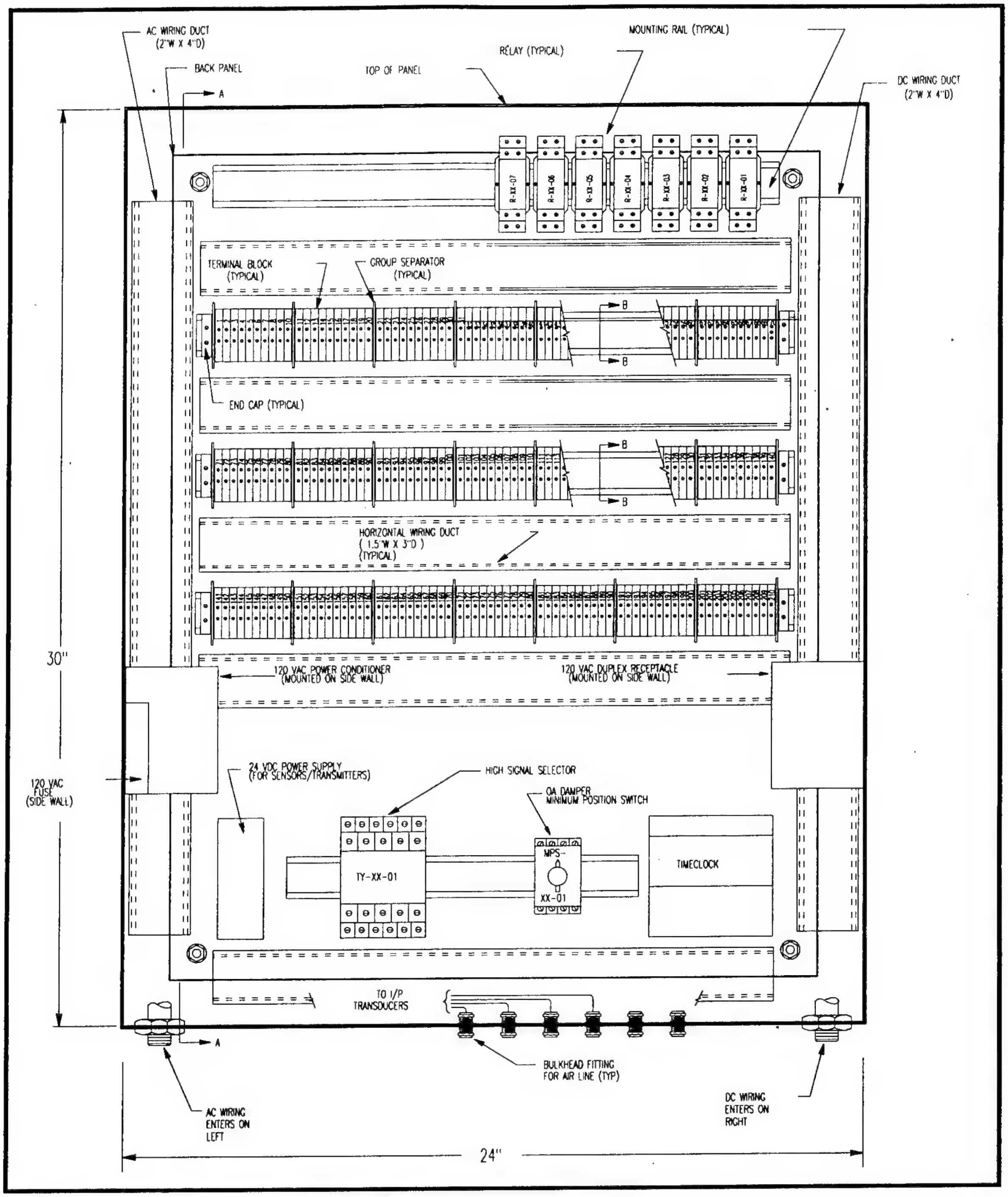


Figure 9. Inside the standard control panel.

4 How To Troubleshoot Control Systems

Introduction

If you get a call that a building is too cold, it may be easy to determine that the boiler is not on. With a little work, you could override the controls that turn the boiler on and off and as a result you force the boiler into operation. A few days later, you get a call that the building is too hot. So now you go back and turn the boiler off. You could find yourself running back and forth indefinitely. Your time would be better spent figuring out why the boiler is not turning itself on and off. The troubleshooting techniques in this manual focus on identifying and fixing the causes of HVAC control problems.

Effective troubleshooting requires you to assess the big picture. You get a "too hot" call and, after poking around, you determine that the source of the problem is a wide open outside air damper. The easy fix is to disconnect the air line or power source to the damper actuator. You have solved the immediate problem, but have likely initiated an indoor air quality problem. In addition, you have eliminated the possibility of getting free cooling (from your economizer cycle), which might come in handy the next time the chiller is down. In this example, your best approach would be to step back and look at the bigger picture. The outside air damper is only one of several components in a control loop. Some of these components interact with (are controlled by) components from other control loops. This can be intimidating, but even the most complex control system can be fixed using a methodical and logical approach.

Tools

Maintenance on the standard control systems and panels will require a basic set of tools. Specifications for spare parts can be found in CEGS-15950. The specifications are specific and include requirements to ensure that each device is non-proprietary. Therefore, they are interchangeable between manufacturers. As a result, a single replacement item should be able to replace any like item in any control panel.

A basic tool kit consists of the following items:

- flat tip and Phillips screwdrivers
- digital multimeter
- 0 to 30 psi pressure gage
- wire stripper
- adjustable wrench
- calculator (optional)
- jewelers (small) screwdriver set
- digital thermometer
- wire cutter
- 18-gage wire
- RTD/mA calibrator.

Basic Troubleshooting Steps

Troubleshooting a control system should be done using a systematic approach. Usually the trouble call is "too hot" or "too cold." Keep in mind that HVAC problems can generally be categorized as being either a system equipment problem or a controls problem. In many cases the source of the problem is evident, but the underlying cause may not be so evident. Try to find and fix the cause, particularly if it is a controls problem. This approach will result in less work for you in the long run. A basic, quick check of a control panel consists of the following steps:

1. **Do Not Start Pushing Buttons and Switches**. Before attempting to correct operational problems by pushing reset or other buttons, or changing control parameters try to make some observations and isolate the problem.
2. **Observe what equipment is operating or not**. If equipment such as fans, pumps, chillers, or boilers are not operating, it may indicate that there is a system equipment problem. Check to make sure the equipment has power, HOA switches, breakers, and fuses. Remember that equipment may be off due to seasonal operation.
3. **Check Control Panel Indicators**. Look at pilot lights to see which are illuminated. The pilot lights will indicate system operating modes such as enabled and occupied mode. If the system is not indicating that it is enabled, set the enable button. If the occupied light is not on, check the time clock to see that it indicates the proper time and date. If you know how, check the configuration of the clock. If you cannot configure the clock, press the auto override button on the control panel. This overrides the time-clock and places the system in the occupied control mode. If the system operates like this, do not leave it in the override mode.

Consult someone who can help reconfigure the time-clock. It is also good idea to replace the battery that provides backup power in case of a power outage.

Pilot lights also indicate if any system safety interlocks have tripped such as freeze-stats, smoke alarms, or high-static pressure switches. If any of these lights are illuminated, make sure that the conditions that caused the safeties to trip are not still present. If not, push the safety device reset button, and then push the control panel reset button. If the only problem was a tripped safety, the system should resume normal automatic control operation. Observe the controller setpoints and measured process variable. They should be closed. It is also a good idea to check local indicators (thermometers, gauges etc.) to determine if the value being displayed by the controller is close to the indicators value. Also observe other lights and indicators that may be illuminated on the controller.

4. **Report observed conditions to a qualified mechanic or controls representative.** If the basic steps do not solve the problem, write down your observations and contact a qualified mechanic or service representative. With the information from your observation, they may be able to diagnose the problem and assist with correcting the problems. If they cannot diagnose the problem from the basic observations, they will have to perform advance troubleshooting steps to diagnose and correct the problem.

Advanced Troubleshooting Steps

1. **Get the big picture.** Read or be familiar with the *Posted Instructions* particularly the sequence of operation and control schematics. Identify the type of HVAC system you are working with (multizone, VAV, single-zone, hot water heating, etc.). Some different control system types are described later in this chapter. Recognize and understand the interfaces or interlocks between the HVAC control panel and the system equipment (such as air handlers, boilers, boiler pumps, chillers, chilled water pumps, and packaged equipment). Seeing the big picture will help you during the troubleshooting process because different types of systems and equipment are prone to different types of problems.
2. **Check the control panel indicator lamps on the inner door.** The indicator lamps and push buttons are described in the *Control Panel Operation* chapter.
   a. If the fan is not running check that the "Enable/off" button is pushed to "Enable."
   b. If the fan is not running and none of the alarm pilot lights are illuminated, try pressing the "Reset" button (on the far left end of the pilot light row).

c. If the fan is not running, check to see if the "occupied" pilot light is illuminated. If not, press the "occupied override" push button. If the fan starts, there may be a problem with the time clock.
d. If the fan is not running, and the "Low Temperature" pilot light is illuminated, find the freeze stat, press its reset button, then press the control panel "Reset" button (on the far left end of the pilot light row).
e. If the fan is not running, and the "High Static" pilot light is illuminated press the control panel "Reset" button (on the far left end of the pilot light row).

3. **Check the controller displays.** The upper display is the process variable (temperature, pressure, humidity, or flow). The lower display shows the setpoint. The upper and lower displays should be near or exactly the same. There are exceptions to this rule. For example, with the economizer controller and the outside air temperature controller, the upper and lower displays do not need to be the same. There are other fairly obvious exceptions. A heating system (hot water temperature) controller, for example, will not have the same upper and lower displays if the boiler is off during the summer. If you suspect that a controller is not functioning properly refer to Chapter 5, "Control Loop Troubleshooting," or Chapter 6, "Hardware Troubleshooting."
4. **Check the control loops.** If as a result of step 2 or 3 you have narrowed the problem down to a heating or cooling system problem, refer to the appropriate heating or cooling loop in Chapter 5, "Control Loop Troubleshooting."
5. **Check the hardware.** If as a result of step 2, 3, or 4 you have narrowed the problem down to a specific piece of control hardware, refer to the manufacturers installation and operation manual or Chapter 6, the "Control Hardware Troubleshooting."

Control System Types

Effective troubleshooting requires familiarity with the big picture. While most HVAC control systems require the same basic approach, as described in the Troubleshooting Steps above, recognition and an understanding of the functions of the different types of common HVAC systems will make troubleshooting quicker and more effective. This section describes some common airside HVAC control systems and some of their operation and maintenance issues.

Multizone System

The Multizone (MZ) system is one of the most O&M friendly HVAC systems because all of the mechanical equipment is located at the air handler (in the mechanical room). As shown in Figures 10 and 11, the air handler contains a heat-

ing coil and cooling coil. There is one heating coil and one cooling coil shared by all the zones. The discharge area from each of these coils is often referred to as the hot deck and cold deck (immediately upstream of the zone dampers). Mounted on the side of the air handler are a series of damper actuators, one for each zone. Although not shown in the Figure, the example AHU would have a total of four actuators. Each actuator positions a cold deck damper and a hot deck damper, which are mechanically linked so that a single actuator moves both dampers in sequence. Each actuator is positioned by a signal from a zone thermostat. The Figure only shows one thermostat, although the example system would have four (one for each zone). The thermostat usually has a temperature (setpoint) adjustment available to the occupant. When the space temperature falls below the setpoint, the thermostat sends a signal to the actuator, which moves the hot deck damper towards open and the cold deck damper towards closed. When the space temperature rises above the setpoint, the thermostat sends a signal to the actuator, which moves the hot deck damper towards closed and the cold deck damper towards open.

A multizone system is constant air volume system, which means that the air volume delivered to each space remains constant. This is achieved through sequencing of the zone dampers; when the hot deck damper is full open, the cold deck damper is full closed. When the hot deck damper is half open, the cold deck damper is also half open.

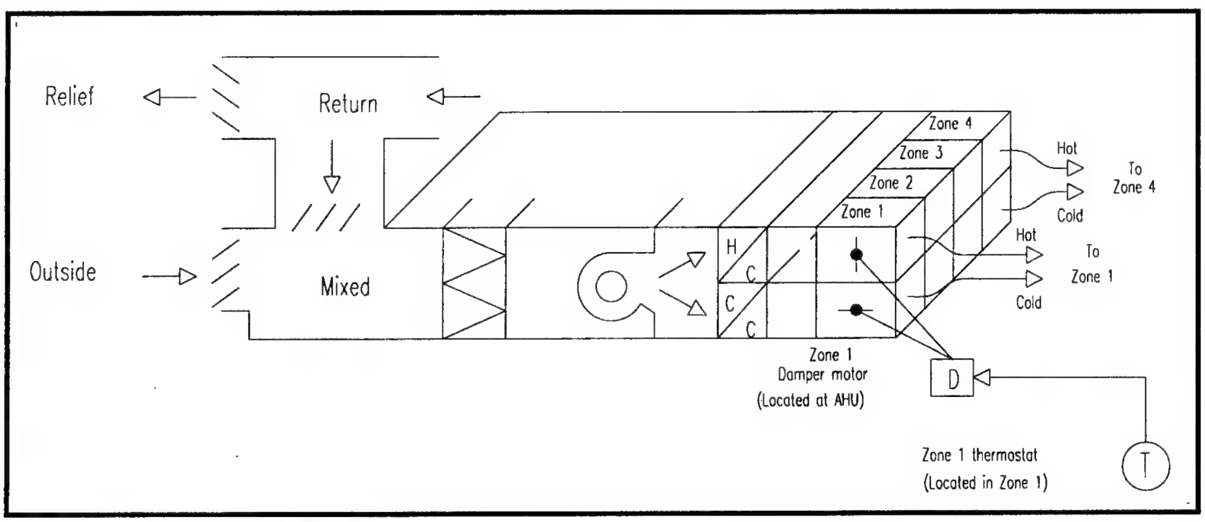


Figure 10. Multizone air handler.

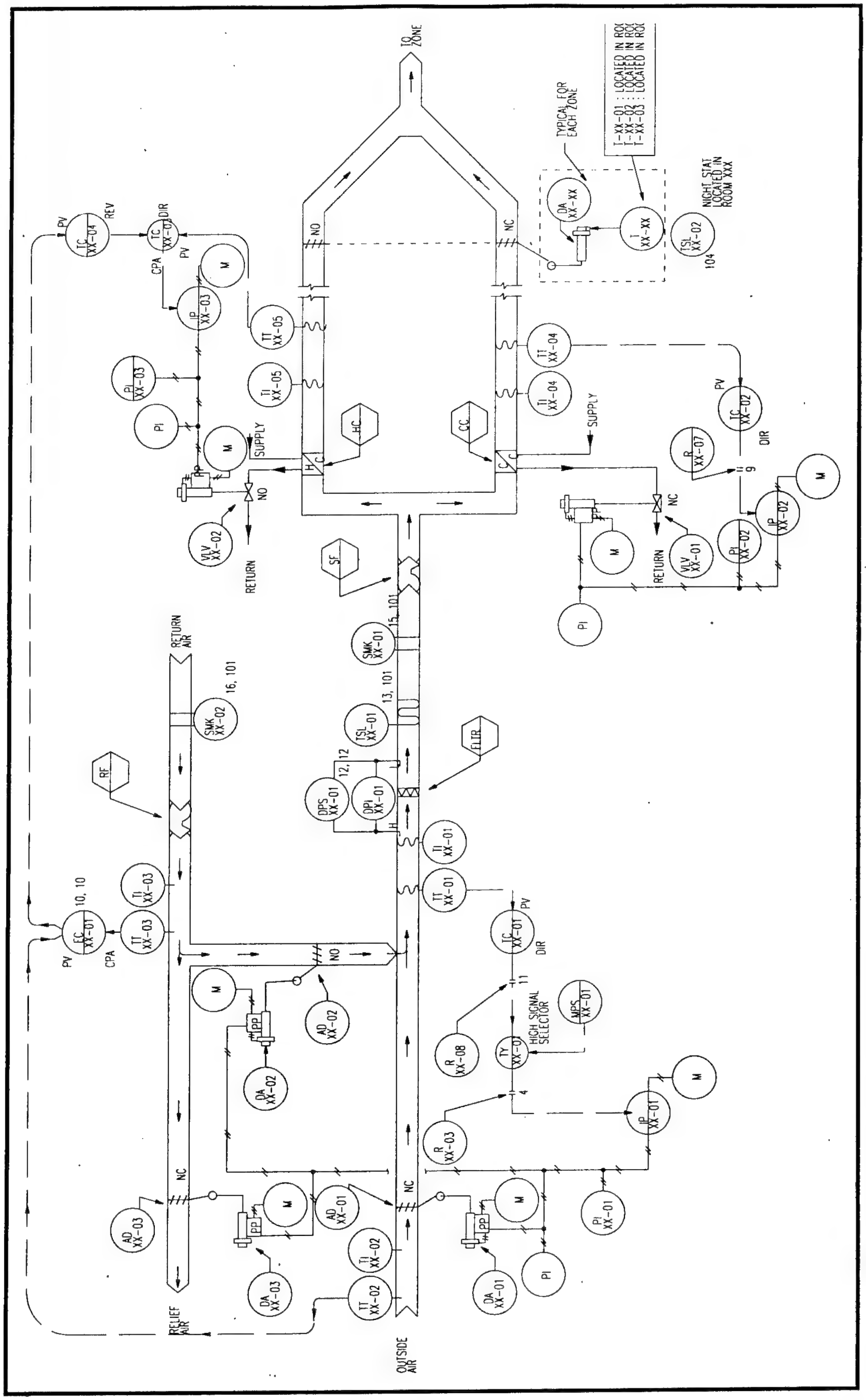


Figure 11. Multizone system control schematic.

The heating and cooling coils each have a dedicated controller. Figure 11 shows the hot and cold deck coil control loops. The cold deck controller setpoint is usually set to 55 °F. The hot deck controller setpoint is usually set to somewhere between 90 and 120 °F.

Multizone Operation and Maintenance Issues

Refer to the "Control Panel Operation" chapter for a description of pushbuttons and pilot lights located on the control panel. The ladder diagram in Figure 12 shows the function of each of the pushbuttons and pilot lights.

As described in Chapter 2, "Using Posted Instructions," the Equipment Schedule (Figure 13) shows the various device settings and ranges.

The hot and/or cold decks are operated seasonally in some multizone systems where the O&M staff shut down the boiler/chiller seasonally.

The heating and cooling coil control loops and the controller settings are explained in detail in the Control Loop Troubleshooting Chapter.

In some cases, the hot deck controller setpoint might be adjusted by an outside air temperature controller to adjust the hot deck temperature setpoint as the outside air temperature changes. Refer to the Heating Coil Control Loop (Figure 22) in Chapter 5, "Control Loop Troubleshooting" for a description this control loop feature and the controller settings.

Proper operation of each zone damper actuator can be verified by individually adjusting each zone thermostat and observing full range movement of the actuators mounted on the side of the AHU. To fully confirm proper operation, first check that the hot and cold deck temperatures are reasonable, then as you adjust each thermostat, confirm movement of the respective actuator and measure (at a zone diffuser) the temperature of the air delivered to the space or zone.

Some multizone systems use an economizer to take advantage of free cooling from outside air. Refer to the Economizer/Mixed Air Control Loop in the Control Loop Troubleshooting Chapter for a description this control loop feature and the controller settings.

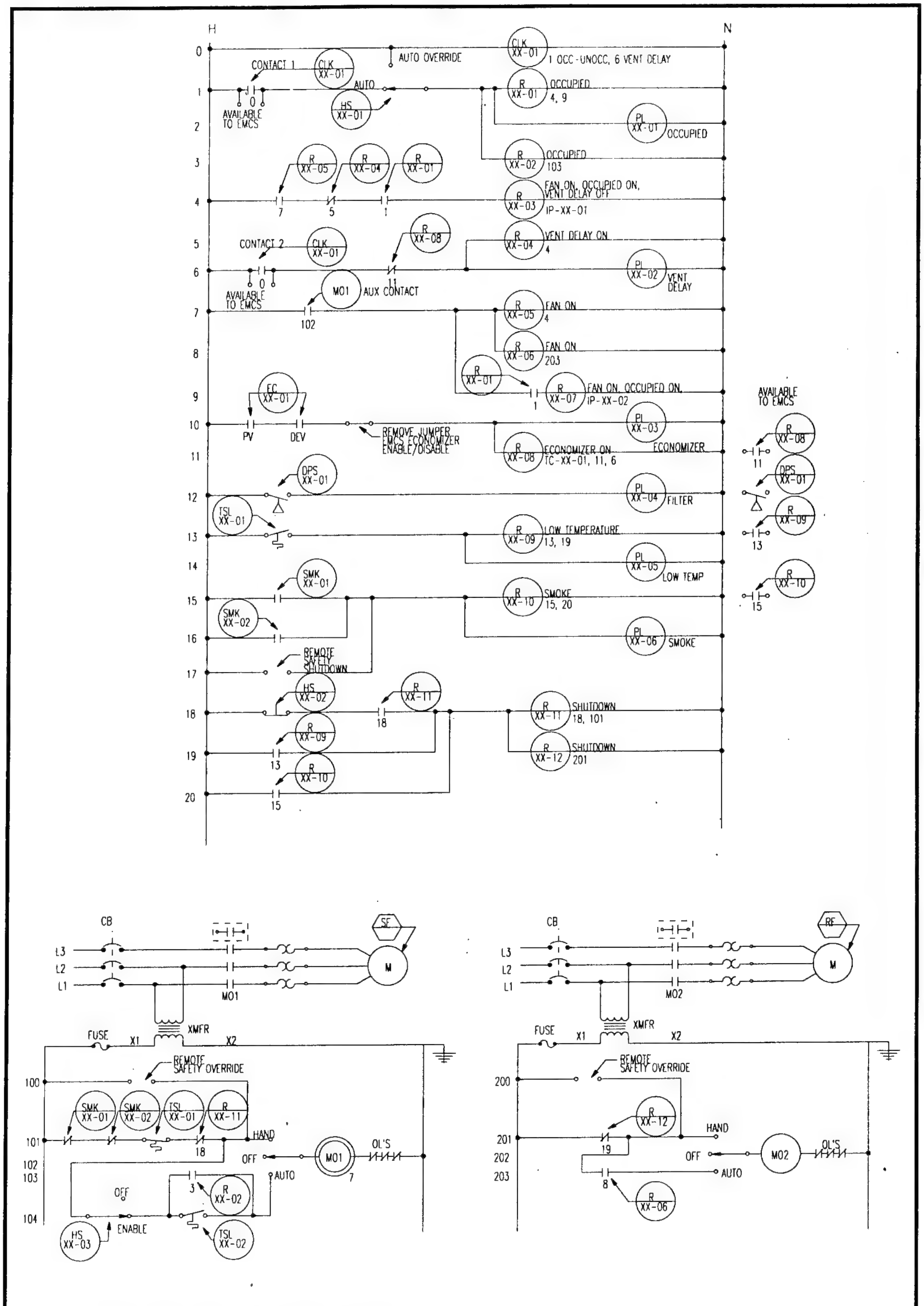


Figure 12. Multizone system ladder diagram.

LOOP FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
MIXED AIR TEMPERATURE	DA-XX-01 DA-XX-02 DA-XX-03	DAMPER ACTUATOR	—	21-103 kPa (3 - 15 PSIG)	—
	MPS-XX-01	MINIMUM POSITION SWITCH	—	—	SET MIN OA L/s (CFM) EQUAL TO _ L/s (_ CFM)
	TC-XX-01	MIXED AIR TEMPERATURE CONTROLLER	13 DEG C (55 DEG F)	4 TO 60 DEG C (40 TO 140 DEG F)	—
	TT-XX-01	MIXED AIR TEMPERATURE TRANSMITTER	—	4 TO 60 DEG C (40 TO 140 DEG F)	—
	TT-XX-02	OUTSIDE AIR TEMPERATURE TRANSMITTER	—	-34 TO 54 DEG C (-30 TO +130 DEG F)	—
	TT-XX-03	RETURN AIR TEMPERATURE TRANSMITTER	—	-34 TO 54 DEG C (-30 TO +130 DEG F)	—
	EC-XX-01	ECONOMIZER CONTROLLER	PV CONTACT CLOSE AT _ DEG C (_ DEG F) OPEN AT _ DEG C (_ DEG F)	-34 TO 54 DEG C (-30 TO +130 DEG F)	DEV CONTACT CLOSE @ DELTA T= _ DEG C (_ DEG F) OPEN @ DELTA T= _ DEG C (_ DEG F)
	TSL-XX-01	FREEZESTAT	2 DEG C (35 DEG F)	3 DEG C DIFFERENTIAL (5 DEG F DIFFERENTIAL)	—
	DPS-XX-01	FILTER ALARM	PER FILTER MANUFACTURER'S RECOMMENDATION	PER FILTER MANUFACTURER'S RECOMMENDATION	—
SPACE LOW TEMPERATURE	TSL-XX-02	NIGHT STAT - SPACE LOW TEMPERATURE PROTECTION	13 DEG C (55 DEG F)	3 DEG C DIFFERENTIAL (5 DEG F DIFFERENTIAL)	—
COLD DECK AIR TEMPERATURE	VLV-XX-01	COOLING COIL VALVE	—	21-103 kPa (3 - 15 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	TC-XX-02	COLD DECK TEMPERATURE CONTROLLER	14 DEG C (57 DEG F)	4 TO 60 DEG C (40 TO 140 DEG F)	—
	TT-XX-04	COLD DECK TEMPERATURE TRANSMITTER	—	4 TO 60 DEG C (40 TO 140 DEG F)	—
HOT DECK AIR TEMPERATURE	VLV-XX-02	HEATING COIL VALVE	—	21-103 kPa (3 - 15 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	TC-XX-03	HOT DECK TEMPERATURE CONTROLLER	OA TEMP = 0 DEG F, HOT DECK = 120 DEG F OA TEMP = 60 DEG F, HOT DECK = 90 DEG F OA TEMP = -18 DEG C, HOT DECK = 49 DEG C OA TEMP = 16 DEG C, HOT DECK = 32 DEG C	PV = 40 TO 140 DEG F CPA = 90 TO 120 DEG F PV = 4 TO 60 DEG C CPA = 32 TO 49 DEG C	CPA LO-LIMIT = 32 DEG C (90 DEG F) CPA HI-LIMIT = 49 DEG C (120 DEG F)
	TC-XX-04	OUTSIDE AIR TEMPERATURE CONTROLLER	SET POINT = -1 DEG C (30 DEG F) PROPORTIONAL BAND = 37.5 % MANUAL RESET = 50 %	-34 TO 54 DEG C (-30 TO +130 DEG F)	—
	TT-XX-05	HOT DECK TEMPERATURE TRANSMITTER	—	4 TO 60 DEG C (40 TO 140 DEG F)	—
OCCUPIED MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE (M-F) CONTACT CLOSED: 0705 HRS CONTACT OPEN: 1700 HRS	CONTACT OPEN: SAT, SUN
VENTILATION DELAY MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE (M-F) CONTACT CLOSED: 0700 HRS CONTACT OPEN: 0800 HRS	

NOTE: OTHER CONTROL DEVICES SUCH AS I/Ps, RELAYS, AND SIGNAL SELECTERS ARE NOT SHOWN.

Figure 13. Multizone system equipment schedule.

Variable Air Volume System

Variable air volume (VAV) systems tend to be more complex than constant volume systems (such as the multizone and singlezone HVAC systems). The VAV system, as shown in Figure 14, consists of a primary air handler, usually located in a mechanical room, but also has a number of VAV boxes (or terminal units) usually located in ceiling of the spaces served by the air handler. VAV boxes come in a variety of configurations. Two very common types of VAV box configurations are cooling only and cooling with reheat (electric or hot water). VAV boxes contain controllers that are usually mounted on the side of the VAV box. Connected to the controller is a space-mounted thermostat. It is beyond the scope of this manual to describe these controls, but it is advisable and would be helpful for the mechanic to get familiar with and understand the function of these controls.

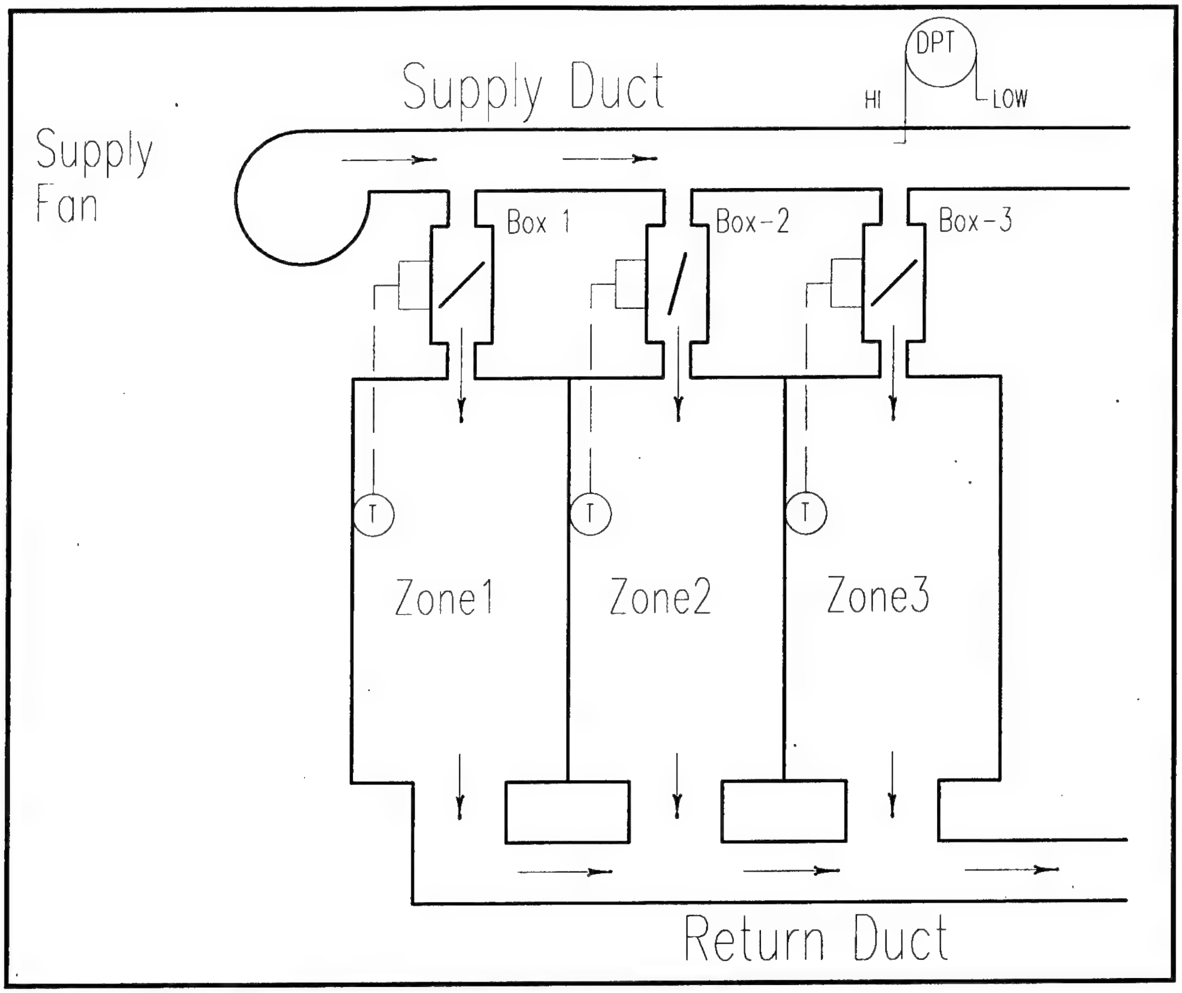


Figure 14. Typical VAV system.

The air handler in a VAV system is a cooling only unit. It is designed to deliver cool air to the VAV boxes. As the temperature in the space served by the VAV box changes, the space thermostat signals the VAV box controller to change the damper position to adjust the amount of cool air delivered to the space. As the damper modulates, the volume of air delivered to the space changes. As the air volume changes, the total air volume being delivered by the air handler changes and, at the same time, the pressure in the duct system changes. VAV boxes are designed to provide adequate airflow only if the duct pressure is sufficiently high that the pressure can push air through each VAV box. As a result, in a VAV system, a duct static pressure sensor is used to measure (sense) duct static pressure. As the pressure drops off, the sensor signals a pressure controller, which in turn increases air handler fan capacity. There are two common methods to modulate fan capacity: adjustable speed fan (sometimes called a variable frequency drive unit) or inlet guide vanes. Inlet guide vanes consist of a series of dampers arranged in a circular pattern and located at the inlet to the blower wheel. As they close, they cause a pre-rotation of the air, which in turn reduces fan capacity.

The VAV system in Figure 15 also has a return fan, as will often be the case with VAV systems. The purpose of the return fan is to ensure that zone air is returned to the air handler. The return fan controller measures both supply and return air flows and is set-up to return slightly less air than that supplied to the zones. This helps to maintain the zones at positive pressure, which reduces infiltration of dust, dirt, and cold air drafts. It also helps to make doors and windows operate properly.

Figure 15 shows the cooling coil control loop, which is used to maintain the coil discharge air temperature setpoint usually at 55 °F. Figure 16 shows typical VAV box temperature controls and the controls sequencing.

VAV Operation and Maintenance Issues

Refer to the "Control Panel Operation" chapter for a description of pushbuttons and pilot lights located on the control panel. The ladder diagram in Figure 17 shows the function of each of the pushbuttons and pilot lights.

As described in the "Using Posted Instructions" chapter, the various device settings and ranges are shown in the Equipment Schedule (Figure 18).

Some VAV systems contain a small heating coil in the air handler that is used as a preheat coil.

Not all VAV systems use fan capacity control. Some VAV systems use a constant volume air handler and either bypass VAV boxes or one or more pressure relief VAV boxes. The thing to be aware of here is that even if your air handler fan does not have capacity control, you might still have a VAV system and therefore VAV boxes located out in the individual spaces.

VAV boxes are almost always located in/above ceilings. Microprocessor based (digital) controls are very common. Access to a handheld operators terminal (hot) is critical to performing maintenance functions. The HOT usually plugs into the zone thermostat via an RJ-11 or RJ-45 jack. In some cases you might have to plug directly into the controller mounted on the side of the VAV box.

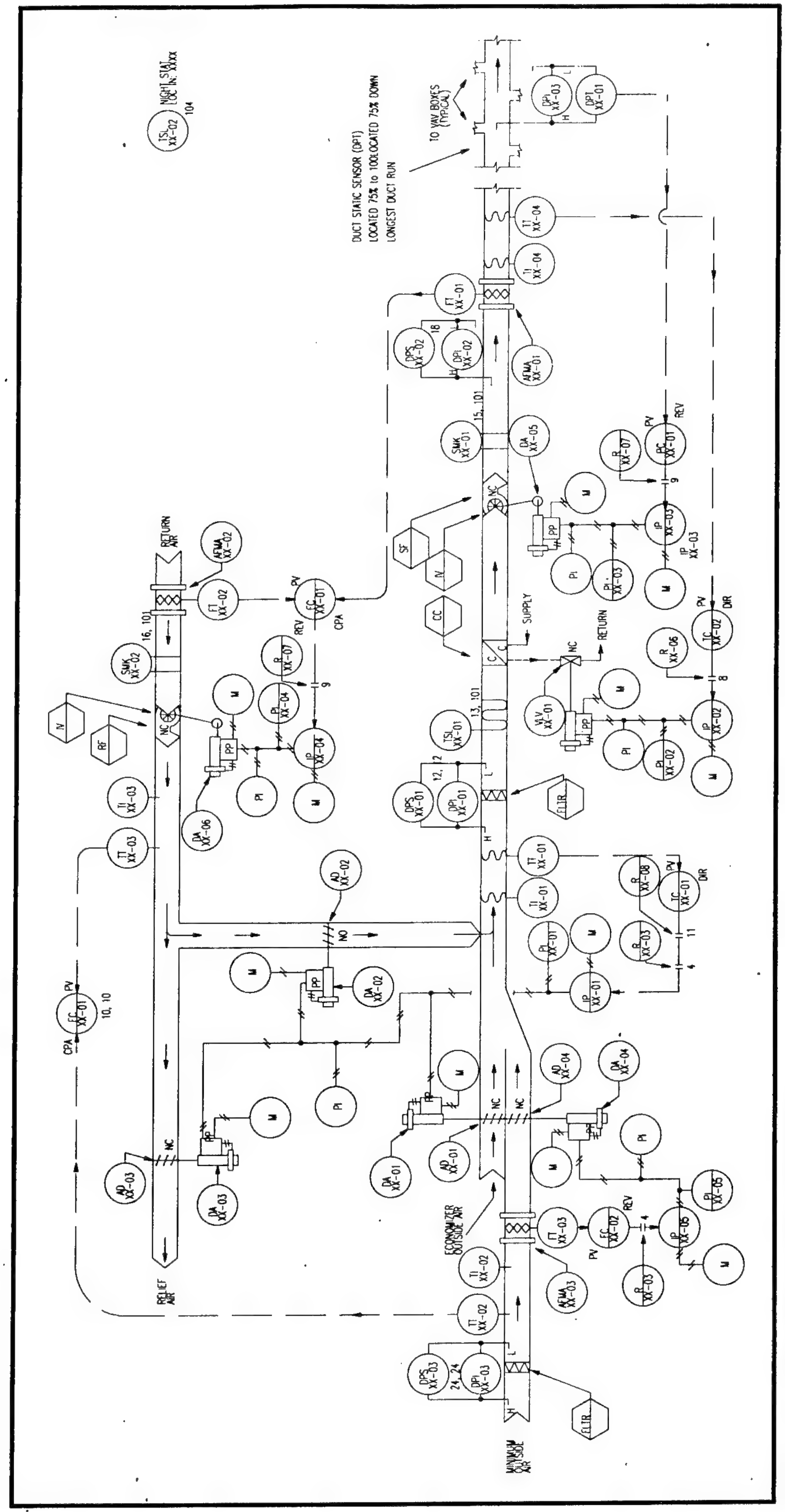


Figure 15. VAV system control schematic.

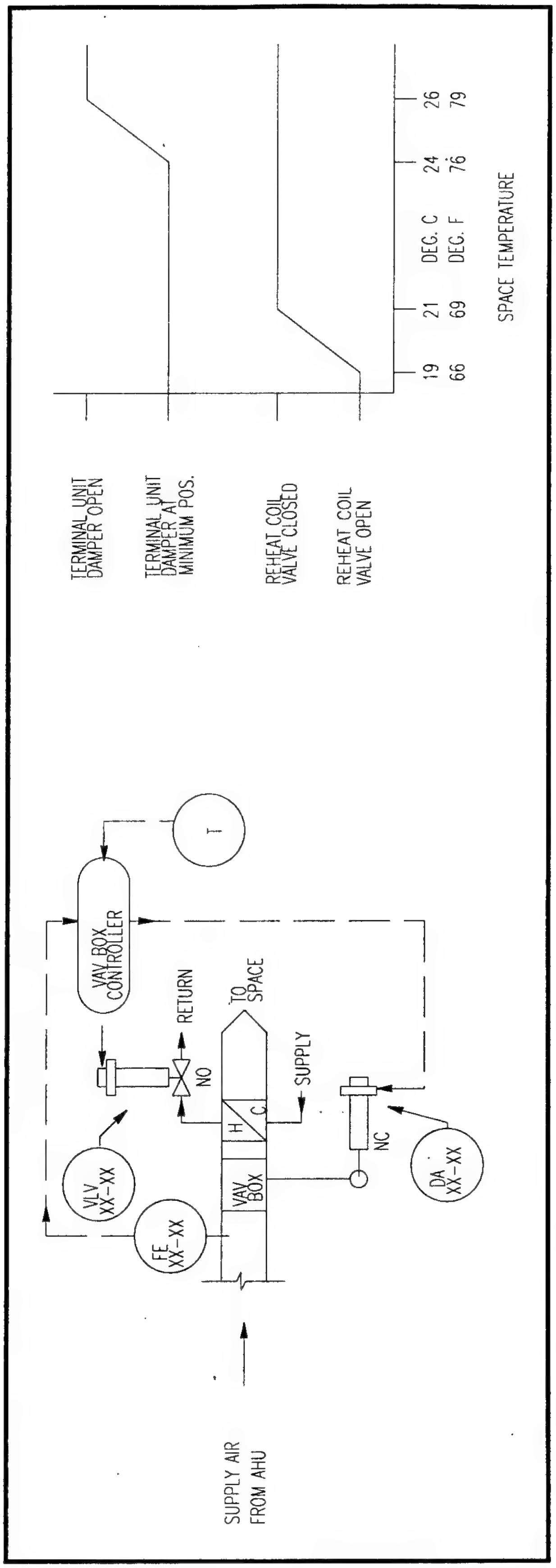


Figure 16. VAV system zone VAV box controls and VAV box control sequencing diagram.

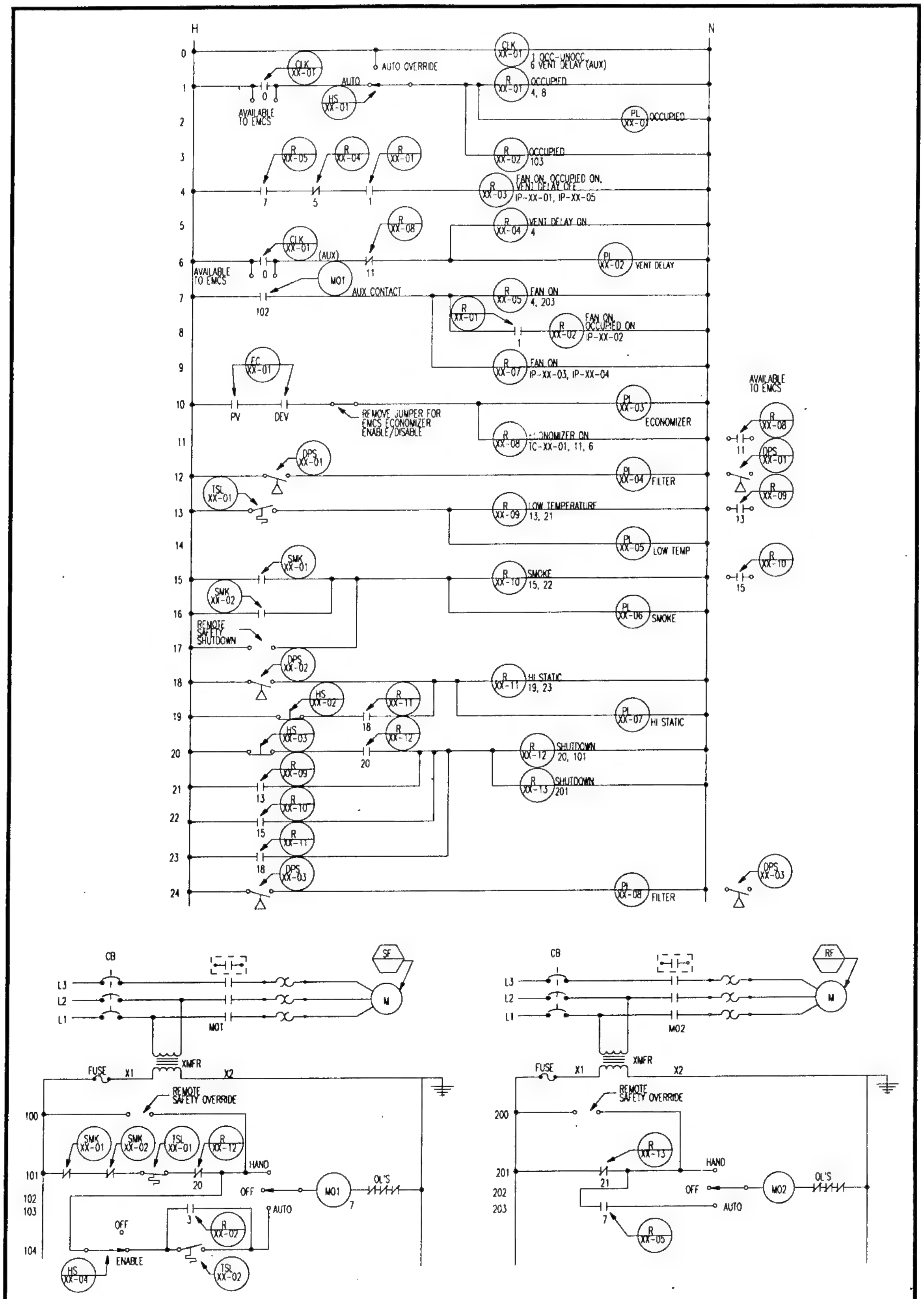


Figure 17. VAV system ladder diagram.

Some VAV systems use an economizer to take advantage of free cooling from outside air. Refer to Figure 42, "Mixed Air with Economizer Control Loop" in Chapter 5, "Control Loop Troubleshooting," for a description this control loop feature and the controller settings.

Single-Zone System

The Single Zone (SZ) system is an O&M friendly HVAC system because all of the mechanical equipment is located at the air handler (in the mechanical room). The air handler contains a heating coil and cooling coil (Figure 19). As the term Single Zone implies, the SZ system is intended to serve only one zone. The zone can consist of several different rooms, but the rooms should have very similar heating and cooling needs. The zone will have a thermostat or sensor located on the wall or in some cases in the return duct. In the Corps standard control system, a sensor (TT-XX03) (not a thermostat) is located in the space. The sensor signals the space temperature controller (located inside the control panel), which in turn positions the heating and cooling valves (and in some cases, the controller also positions the mixed air economizer dampers).

The space temperature controller shown in Figure 19 has an occupant adjustable setpoint via the temperature setpoint (TSP-XX01) device located in the space. The adjustment range limits can be set at the space temperature controller located in the control panel. The economizer controller, located inside the control panel, takes advantage of free cooling from outside air. Figure 42 describes this control loop feature and the controller settings.

Single Zone Operation and Maintenance Issues

Refer to the "Control Panel Operation" chapter for a description of pushbuttons and pilot lights located on the control panel. The ladder diagram in Figure 20 shows the function of each of the pushbuttons and pilot lights. As described in the "Using Posted Instructions" chapter, the various device settings and ranges are shown in the Equipment Schedule (Figure 21). The space temperature and the mixed air/economizer control loops and the controller settings are explained in detail in the Control Loop Troubleshooting Chapter.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
MIXED AIR TEMPERATURE	DA-XX-01 DA-XX-02 DA-XX-03	DAMPER ACTUATOR	—	21 - 103 kPa (3-15 PSIG)	—
	TC-XX-01	MIXED AIR TEMPERATURE CONTROLLER	13 DEG C (55 DEG F)	4 TO 60 DEG C (40 TO 140 DEG F)	—
	TT-XX-01	MIXED AIR TEMPERATURE TRANSMITTER	—	4 TO 60 DEG C (40 TO 140 DEG F)	—
	TT-XX-02	OUTSIDE AIR TEMPERATURE TRANSMITTER	—	-34 TO 54 DEG C (-30 TO 130 DEG F)	—
	TT-XX-03	RETURN AIR TEMPERATURE TRANSMITTER	—	-34 TO 54 DEG C (-30 TO 130 DEG F)	—
	EC-XX-01	ECONOMIZER CONTROLLER	PV CONTACT CLOSE AT _ DEG C (_ DEG F) OPEN AT _ DEG C (_ DEG F)	-34 TO 54 DEG C (-30 TO 130 DEG F)	DEV CONTACT CLOSE @ DELTA T= _ DEG C (_ DEG F) OPEN @ DELTA T= _ DEG C (_ DEG F)
	TSL-XX-01	LOW TEMPERATURE PROTECTION THERMOSTAT	2 DEG C (35 DEG F)	—	—
	DPS-XX-01	FILTER ALARM	PER FILTER MANUFACTURER'S RECOMMENDATION	PER FILTER MANUFACTURER'S RECOMMENDATION	—
MIN. OUTSIDE AIR FLOW	DA-XX-04	DAMPER ACTUATOR	—	21 - 103 kPa (3-15 PSIG)	—
	FC-XX-02	MIN. OUTSIDE AIR DUCT FLOW CONTROLLER	Min OA = _ L/s (_ cfm)	0 - _ L/s (0 - _ CFM)	(SEE NOTE 1)
	FT-XX-03	MIN. OUTSIDE AIR DUCT FLOW TRANSMITTER	—	0 - _ m/s (0 - _ FPM)	UPPER RANGE AS REQUIRED (SEE SPECIFICATIONS)
	DPS-XX-03	PRE-FILTER ALARM	PER FILTER MANUFACTURER'S RECOMMENDATION	PER FILTER MANUFACTURER'S RECOMMENDATION	—
SPACE LOW TEMPERATURE	TSL-XX-02	NIGHT STAT - SPACE LOW TEMPERATURE PROTECTION	13 DEG C (55 DEG F)	DIFFERENTIAL = 3 DEG C (5 DEG F)	—
DISCHARGE AIR TEMPERATURE	VLV-XX-01	COOLING COIL VALVE	—	21-103 kPa (3-15 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	TC-XX-02	FAN DISCHARGE TEMPERATURE CONTROLLER	13 DEG C (55 DEG F)	4 TO 60 DEG C (40 TO 140 DEG F)	—
	TT-XX-04	FAN DISCHARGE TEMPERATURE TRANSMITTER	—	4 TO 60 DEG C (40 TO 140 DEG F)	—
SUPPLY DUCT STATIC PRESSURE	DA-XX-05	SUPPLY FAN INLET VANE ACTUATOR	—	21 - 103 kPa (3-15 PSIG)	—
	PC-XX-01	SUPPLY DUCT STATIC PRESSURE CONTROLLER	300 kPa (1.2 INCHES WATER)	0 - 500 kPa (0.0 - 2.0 INCHES WATER)	—
	DPT-XX-01	SUPPLY DUCT STATIC PRESSURE TRANSMITTER	—	0 - 500 kPa (0.0 - 2.0 INCHES WATER)	—
	DPS-XX-02	SUPPLY DUCT - HIGH STATIC PRESSURE SAFETY	—	1000 - 1500 kPa (4.0 - 6.0 INCHES WATER)	—
RETURN FAN VOLUME	DA-XX-06	RETURN FAN INLET VANE ACTUATOR	—	21 - 103 kPa (3-15 PSIG)	—
	FC-XX-01	RETURN FAN VOLUME CONTROLLER	SUPPLY FAN L/s (CFM) MINUS _ L/S (_ CFM)	0 - 9500 L/s (0 - 20,000 CFM)	—
	FT-XX-01	SUPPLY DUCT FLOW TRANSMITTER (FPM)	—	0 - 9500 L/s (0 - 20,000 CFM)	—
	FT-XX-02	RETURN DUCT FLOW TRANSMITTER (FPM)	—	0 - 9500 L/s (0 - 20,000 CFM)	—
OCCUPIED MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE (M-F) CONTACT CLOSED: 0705 HRS CONTACT OPEN: 1700 HRS	CONTACT OPEN: SAT, SUN
VENTILATION DELAY MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE (M-F) CONTACT CLOSED: 0700 HRS CONTACT OPEN: 0800 HRS	
TERMINAL UNITS	VLV-XX-AA	HEATING COIL VALVE SPACE AA	—	—	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	•	•	•	•	•
	VLV-XX-ZZ	HEATING COIL VALVE SPACE ZZ	—	—	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)

NOTES:

1. Upper range (L/s) of flow controller (FC-XX-XX) = Upper range (m/s) of associated flow transmitter (FT-XX-XX) TIMES the duct area (sq m) TIMES 1000 (L/cu. m). (Upper range (CFM) of flow controller (FC-XX-XX) = Upper range (fpm) of associated flow transmitter (FT-XX-XX) TIMES the duct area (sq ft).
2. OTHER CONTROL DEVICES SUCH AS I/Ps, RELAYS, SIGNAL SELECTERS AND TERMINAL UNIT CONTROLLERS ARE NOT SHOWN.

Figure 18. VAV system equipment schedule.

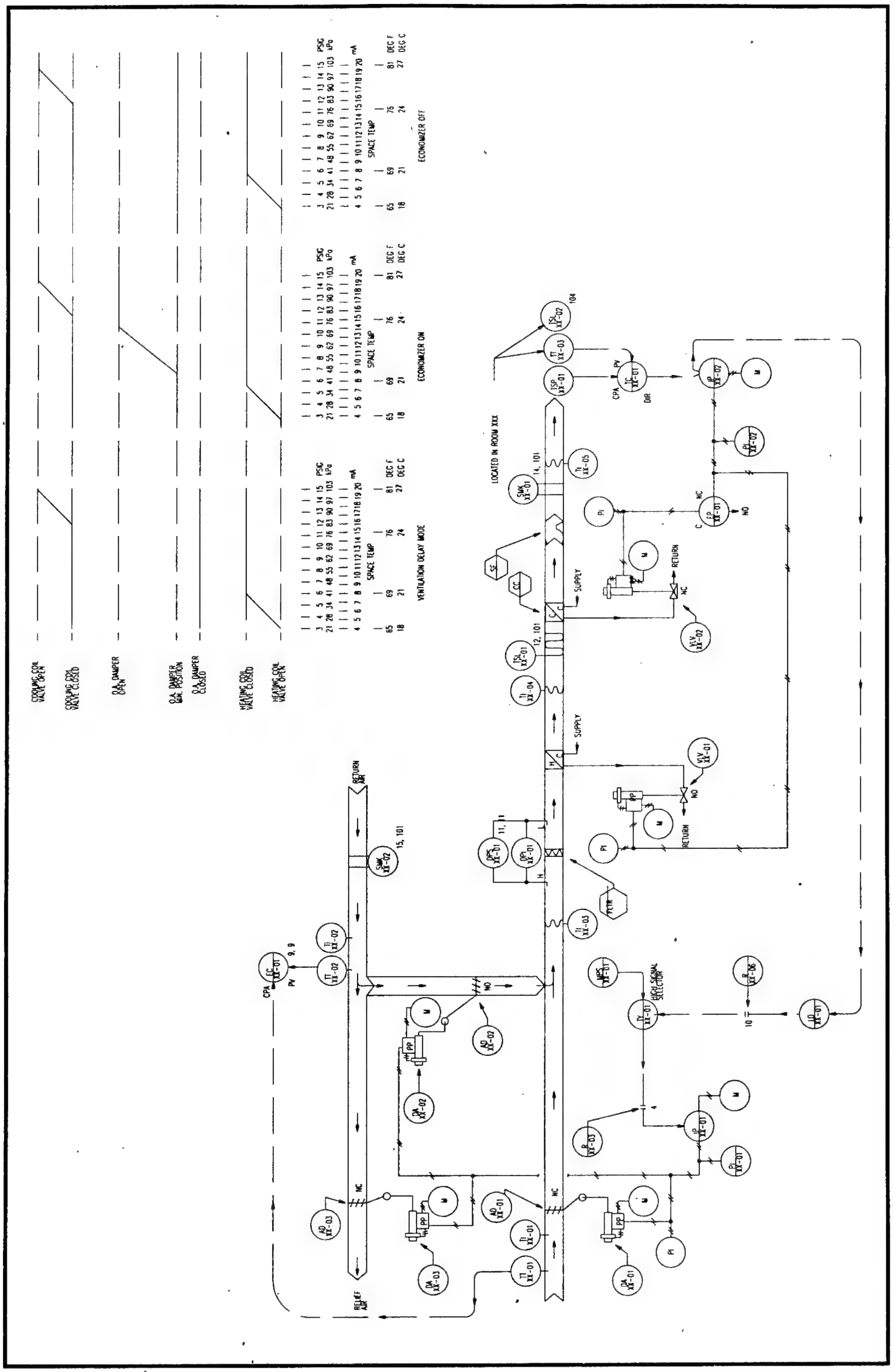


Figure 19. Singlezone system control schematic.

Heating valve, cooling valve, and economizer damper sequencing should be checked before government acceptance of the system and at periodic maintenance regular intervals. The space temperature controller (TC-XX01), as shown in Figure 19, positions the heating and cooling coil valves, and (when the economizer is on) it also positions the mixed air economizer dampers. The controller positions these three devices using its 4–20 mA output signal. The sequencing schematic in the upper right hand corner of Figure 19 shows that the heating valve moves from full open to full closed over a controller signal range of 4-8 mA, the mixed air dampers move from minimum position to full open over a control signal range of 9-13 mA, and the cooling valve moves from full closed to full open over a control signal range of 14 to 20 mA. Proper operation of the device sequencing can be verified by placing the controller in "manual" mode and adjusting the control signal output. Slowly increase the output and observe full range movement of the heating valve, cooling valve, and damper actuators as described above. Verify too that the not only do the actuators stroke, but also that the valves and damper move in the proper direction.

The heating and/or cooling coils are operated seasonally in some single zone systems where the O&M staff shut down the boiler/chiller seasonally. In some single zone systems, nuisance freeze stat trips are possible. This occurs when the space is warm in the winter and as a result, the economizer turns on. When the economizer turns on, it may open the outside air dampers far enough to cause an in-rush of cold (freezing) air, which in turn trips the freeze stat. This can be prevented by: raising the PV contact setpoint of the economizer, and either relocating the space temperature sensor to a cooler location or rewiring the single-loop controller so that the outside air temperature is the PV input and the return air temperature is the RSP input. This later modification also requires reconfiguration of the controller and is a more permanent/definitive fix than the other two. Contact Savannah District, the Technical Center of Expertise (TCX) for HVAC controls, for details.

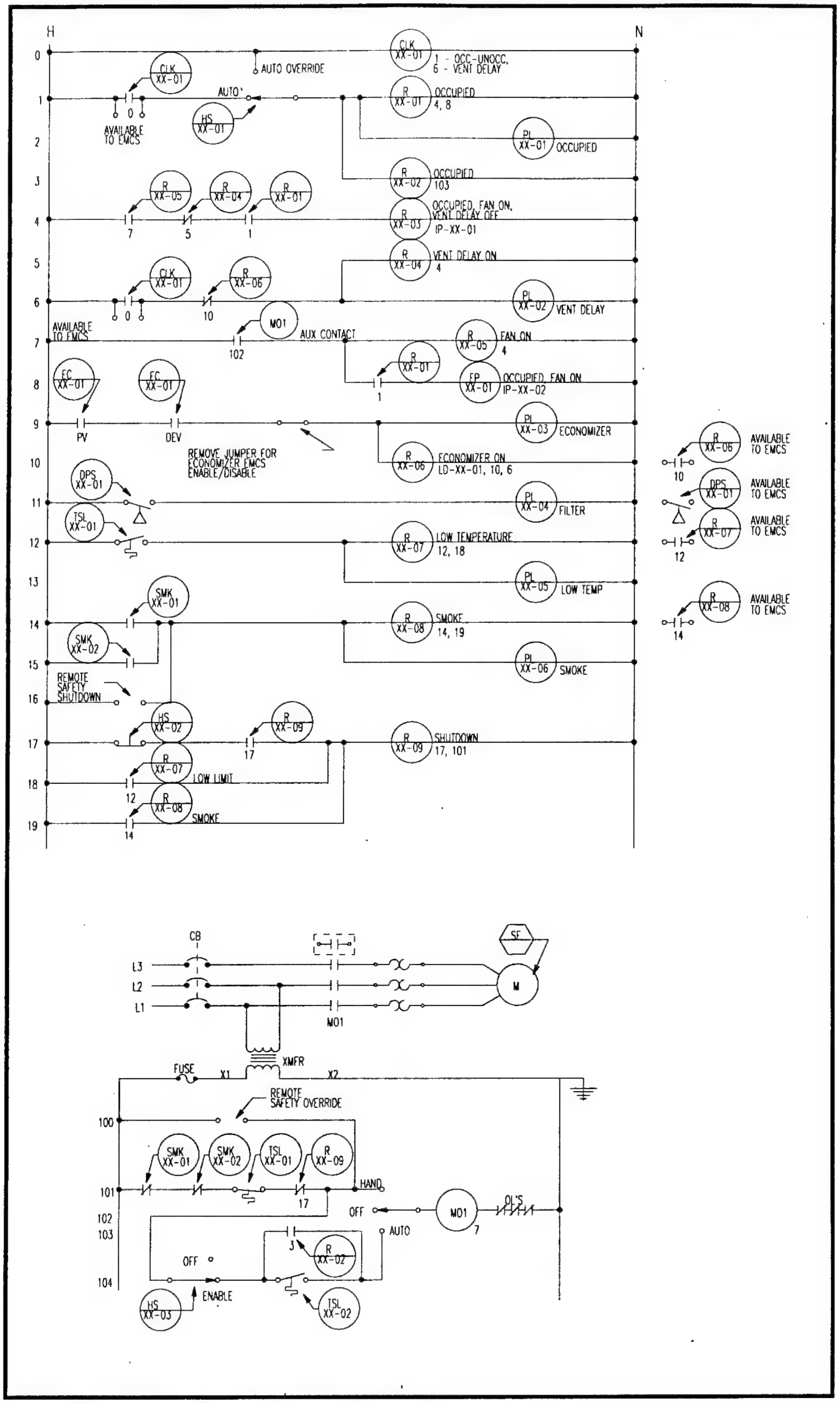


Figure 20. Singlezone system ladder diagram.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
SPACE TEMPERATURE	DA-XX-01 DA-XX-02 DA-XX-03	DAMPER ACTUATOR	—	48 - 76 kPa (7 - 11 PSIG)	—
	MPS-XX-01	MINIMUM POSITION SWITCH	—	—	SET MIN OA L/s (CFM) EQUAL TO _ L/S (_ CFM)
	TT-XX-01	OUTSIDE AIR TEMPERATURE TRANSMITTER	—	-34 TO 54 DEG C (-30 TO +130 DEG F)	—
	TT-XX-02	RETURN AIR TEMPERATURE TRANSMITTER	—	-34 TO 54 DEG C (-30 TO +130 DEG F)	—
	EC-XX-01	ECONOMIZER CONTROLLER	PV CONTACT CLOSE AT _ DEG C (_ DEG F) OPEN AT _ DEG C (_ DEG F)	-34 TO 54 DEG C (-30 TO +130 DEG F)	DEV CONTACT CLOSE @ DELTA T= _ DEG C (_ DEG F) OPEN @ DELTA T= _ DEG C (_ DEG F)
	VLV-XX-01	HEATING COIL VALVE	—	21 - 41 kPa (3 - 6 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	VLV-XX-02	COOLING COIL VALVE	—	83 - 103 kPa (12 - 15 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	TC-XX-01	SPACE TEMPERATURE CONTROLLER	4 mA = 10 DEG C (50 DEG F) 20 mA = 30 DEG C (85 DEG F)	10 TO 30 DEG C (50 TO 85 DEG F)	SET LIMITS AVAILABLE TO OCCUPANT BY TSP-XX-01 AT 19 TO 22 DEG C (66 TO 72 DEG F)
	TT-XX-03	SPACE TEMPERATURE TRANSMITTER	—	10 TO 30 DEG C (50 TO 85 DEG F)	—
	TSP-XX-01	SPACE TEMPERATURE SETPOINT ADJUSTMENT	4 mA = 10 DEG C (50 DEG F) 20 mA = 30 DEG C (85 DEG F)	—	—
MIXED AIR	TSL-XX-01	LOW TEMPERATURE PROTECTION THERMOSTAT	2 DEG C (35 DEG F)	—	—
	DPS-XX-01	FILTER ALARM	PER FILTER MANUFACTURER'S RECOMMENDATION	PER FILTER MANUFACTURER'S RECOMMENDATION	—
SPACE LOW TEMPERATURE	TSL-XX-02	NIGHT STAT - SPACE LOW TEMPERATURE PROTECTION	13 DEG C (55 DEG F)	DIFFERENTIAL = 3 DEG C (5 DEG F)	—
OCCUPIED MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE (M-F) CONTACT CLOSED: 0705 HRS CONTACT OPEN: 1700 HRS	CONTACT OPEN: SAT, SUN
VENTILATION DELAY MODE	CLK-XX-01 CONTACT	365 DAY SCHEDULE	—	NORMAL SCHEDULE (M-F) CONTACT CLOSED: 0700 HRS CONTACT OPEN: 0800 HRS	

NOTE: OTHER CONTROL DEVICES SUCH AS I/Ps, RELAYS, AND SIGNAL SELECTERS ARE NOT SHOWN.

Figure 21. Singlezone system equipment schedule.

5 Control Loop Troubleshooting

HVAC control systems consist of one or more control loops. When problems occur in an HVAC system, it is important to identify the control loop that is causing the problem. Once the problem control loop is identified, the problem can be narrowed down to components. Typical component problems arise from improperly configured controllers, components that may need calibration, or devices that have failed. Control loops are presented here primarily by describing their related Posted Instructions including:

- control schematic
- ladder diagram
- equipment schedule
- sequence of operation
- configuration checksheet(s) showing typical controller settings and parameters.

For each control loop, important maintenance information, particularly in regard to troubleshooting is listed or described for each Posted Instruction.

It may help to refer to Chapter 3, which describes how to interpret posted instructions, and Chapter 5, which describes troubleshooting control systems.

Many Army buildings were constructed before the release and implementation of standard control schemes. As a result, identical HVAC systems may be controlled differently. This can create maintenance problems because unique control schemes can take more time to isolate component problems and repair the controls. It is suggested that when unique control loops pose repeated problems that they be retrofitted using the standard control loops as shown in this section. Note that there may be slight variations in control loops as they are applied to different systems. Before retrofitting an existing control system it is a good idea to consult your design group or the Technical Center of Expertise (TCX) for HVAC controls at Savannah District. The contact information for the Savannah District TCX is in the appendices.

Preheat and Heating Coil Control Loops

Control Schematic Information

Figure 22 shows the preheat or heating coil control loop.

- TC-XX03 is direct acting, DIR.
- TT-XX05 has an averaging sensing element, is PV input to TC-XX03 analog input 1.
- VLV-XX02 is normally open, NO.

Ladder Diagram

There are no relays or switches shown on the pre-heat coil controls that would appear on a ladder diagram. This control system is designed to fail to full heat, therefore interlocks to devices such as time clocks and supply fans are not used.

Sequence of Operation

Hot deck temperature controller TC-XX-03, with its temperature transmitter TT-XX-05 in the heating coil discharge, modulates hot deck heating coil valve VLV-XX-02 to maintain its temperature setpoint.

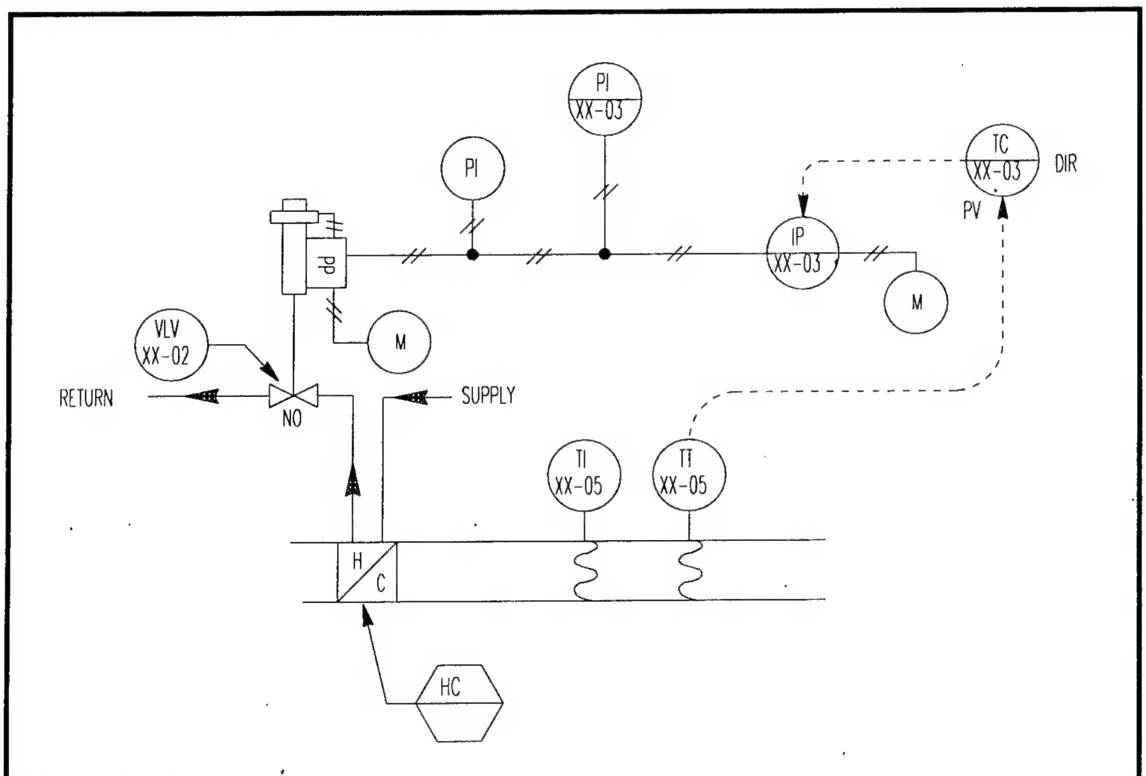


Figure 22. Preheat/heating coil control schematic.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
PRE-HEAT COIL TEMPERATURE	VLV-XX-02	PRE-HEAT COIL VALVE	—	(3 - 15 PSIG)	Cv = CLOSE AGAINST _ PSIG
	TC-XX-03	PRE-HEAT TEMPERATURE CONTROLLER	40 DEG F	-30 TO 130 DEG F	—
	TT-XX-05	PRE-HEAT TEMPERATURE TRANSMITTER	—	-30 TO 130 DEG F	—

Figure 23. Equipment schedule for preheat/heating coil control loop.

Equipment Schedule

Equipment Schedule Information

Figure 23 shows the preheat coil control loop equipment schedule.

- VLV-XX02 Valve flow coefficient (Cv) is important replacement ordering information.
- TT-XX05 Sensor range is -30 to 130 °F.
- TC-XX03 Range is -30 to 130 °F (and must be set to the same range as TT-XX05 sensor range).
- TC-XX03 Setpoint is 40 °F (if the sensor is in the outside air duct, but if the sensor is in the mixed air section the setpoint should be 55 °F).
- TC-XX-03 PB is 15.6 percent, I is 60 seconds.

Preheat Coil Controller Configuration Parameters

If the sensor is immediately downstream of the preheat coil the setpoint should be about 40 °F. If the sensor is in or beyond the mixed air section, the setpoint should be about 55 °F. In a 100 percent outside air application the setpoint should be 55 °F. The percent **proportional band** (PB) depends on the throttling range. A typical **throttling range** (TR) for the preheat coil loop is 25 °F. With a temperature transmitter range (sensor span) of -30 to 130 °F the proportional band is:

$$\begin{aligned} PB &= TR / (\text{OA sensor span}) \times 100 \\ &= 25\ °F / (130\ °F - -30\ °F) \times 100 \\ &= 25\ °F / (130\ °F + 30\ °F) \times 100 \\ &= 25\ °F / (160\ °F) \times 100 \\ &= 15.6\% \end{aligned}$$

Heating Coil Controller Configuration Parameters

The heating coil controller **setpoint** is usually set at 115 °F. The process variable **high and low ranges** are set to match the temperature transmitter (TT) range. The percent **proportional band** (PB) depends on the throttling range. A typical **throttling range** (TR) for the heating coil loop is 25 °F. With a temperature transmitter range (sensor span) of 40 to 140 °F the proportional band is:

PB = TR / (sensor span) x 100

= 25 °F / (140 °F - 40 °F) x 100

= 25 °F / (100 °F) x 100

= 25.0%

Figure 24 shows a preheat controller configuration checksheet.

Preheat/Heating Coil Loop Troubleshooting

If the Symptom is "No Heat":

1. Check Control Panel:

a. Indicator lamps:

(1) Does the Pilot Light indicate a system problem (freezestat, smoke alarm, high static, economizer, etc)?

(2) Is the fan operating? (check pushbuttons: Enable, Auto, Occupied, HOA)

b. Temperature controller:

(1) Is the heating system (boiler) on?

(2) Is the setpoint correct (40° to 55 °F)?

(3) PV Temp should be equal to or close to setpoint (Is TT calibrated?)

PREHEAT COIL CONTROLLER
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Dir (direct or reverse)
Setpoint Derived from	SPF	panel (panel or AI2)
Low limit of setpoint	SPLL	-30 (adjustment lo range)
High limit of setpoint	SPHL	130 (adjustment hi range)
Setpoint	SP–	40 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	Dis
Digital Input 2	dI2-	Dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	130
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	130
Alarm 2 Hysteresis	Hys2	2 (deadband)
Proportional band	P---	15.6 %
Integral value	I---	60 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	o1-	-30 (sensor/TT range)
Process Variable (PV) High Range	HI1-	130 (sensor/TT range)

Figure 24. Preheat coil controller configuration checksheet.

HEATING COIL CONTROLLER
(with fixed setpoint)
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Dir (direct or reverse)
Setpoint Derived from	SPF	Panel (panel or AI2)
Low limit of setpoint	SPLL	40 (adjustment lo range)
High limit of setpoint	SPHL	140 (adjustment hi range)
Setpoint	SP–	115 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dls
Digital Input 2	dI2-	dls
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	140
Alarm 1 Hysteresis	Hys1	0 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	140
Alarm 2 Hysteresis	Hys2	0 (deadband)
Proportional band	P---	25 %
Integral value	I---	60 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	40 (sensor/TT range)
Process Variable (PV) High Range	HI1-	140 (sensor/TT range)

Figure 24. (Cont'd).

(4) Are the controller configuration parameters correct? (Direct Action, PV high and low range, setpoint, PB, etc.)

(5) Is the controller output correct? (See "Controller," p 106, in Chapter 6, "Controller Hardware Troubleshooting"). Does the valve modulate? Does the IP show a pressure signal to the valve? Check the gage at the panel and at the actuator. Is the positive positioner adjusted properly? (See "Positive Positioner," p 117 in Chapter 6, "Controller Hardware Troubleshooting.")

c. Economizer/mixed air:

(1) System should not be in economizer mode when there is a call for heat.

(2) Is the OA damper open?

(3) Check minimum position switch inside panel and OA damper. It should be set to the indicated minimum position.

2. Check hydronic system:

a. Is the pump and boiler operating? Is there water flow? Can you modulate the valve using the controller? Is the strainer clogged?

b. Are HWS and HWR temperatures reasonable (HWS 180 °F or per reset schedule, HWR no more than 25 °F less than HWS). Check temperatures at the boiler and at the problem coil.

3. Check the air handler. Is there air flow? Is the fan on? Is the airside of the coil clogged with debris? Is the air filter dirty?

Heating Coil Loop with Setpoint Reset

Figure 25 shows the heating coil loop with setpoint reset.

Control Schematic Information

- TT-XX04 is reverse acting, REV.
- TT-XX02 is the PV input for TC-XX04, analog input 1, it is also AI2 for EC-XX01.
- TC-XX03 is direct acting, DIR.
- TT-XX05 has an averaging sensor, is the PV input analog input 1 for TC-XX03.
- Analog output of TC-XX04 is the CPA, analog input 2, of TC-XX03.
- VLV-XX02 is normally open (NO) to the HW return.

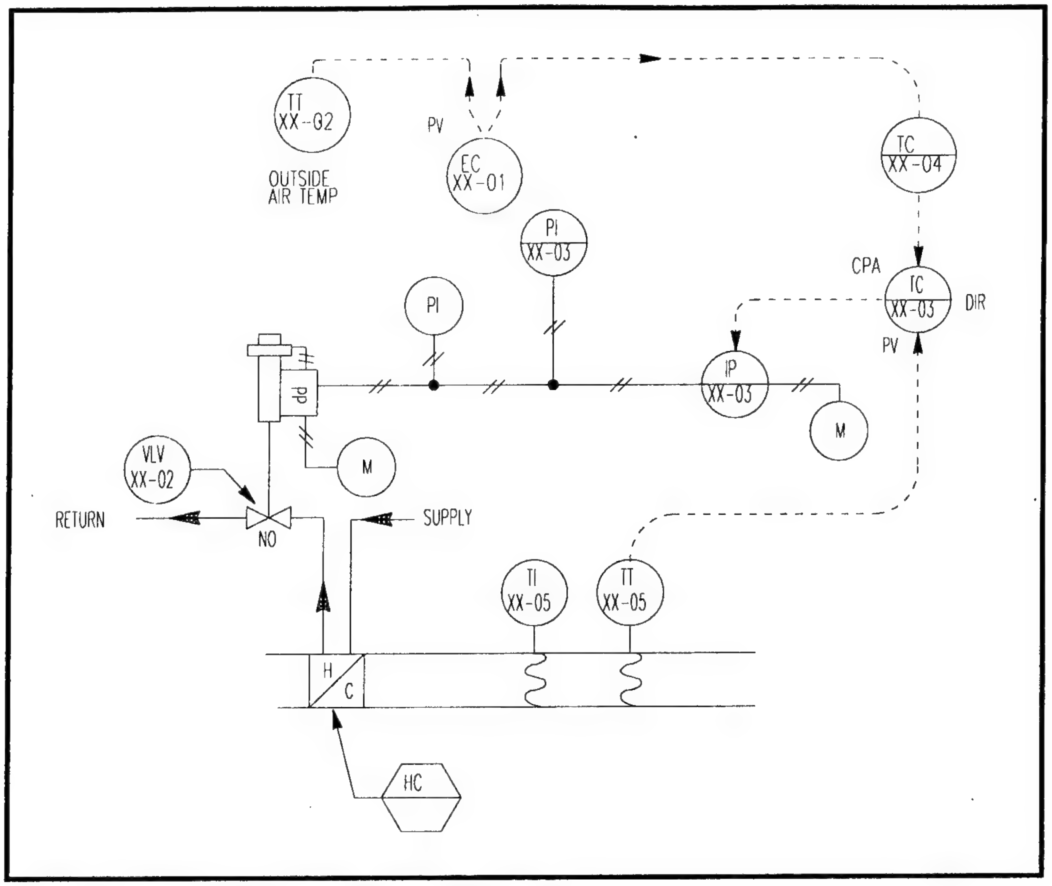


Figure 25. Heating coil loop with setpoint reset.

<u>OA Temp</u>	<u>Supply Air Setpoint</u>
0 °F	120 °F
60 °F	90 °F

Maximum Supply air setpoint = 120 °F

<u>Reset Schedule Information</u>

Figure 26 shows a reset schedule for the heating coil control loop.

TC-XX04 throttling range is 60 °F (0 to 60 °F)

TC-XX03 low limit of setpoint is 90 °F, and high limit of setpoint 120 °F

TC-XX03 calibration values for AI2 setpoint are low limit 90 °F, high limit 120 °F

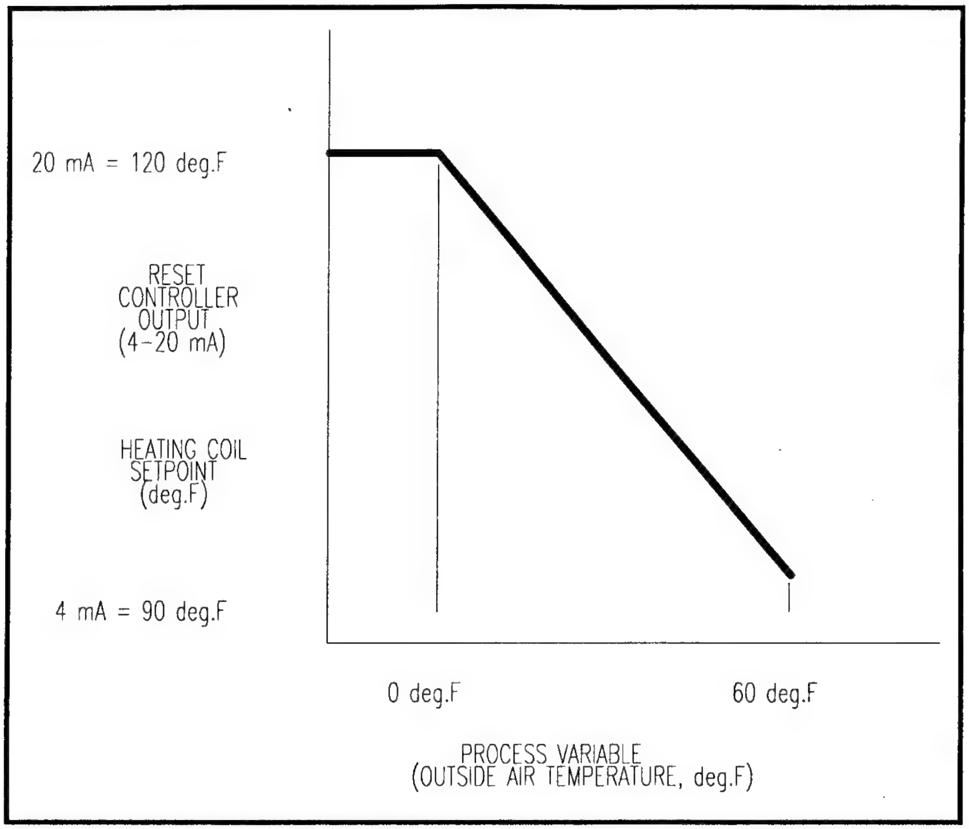


Figure 26. Reset schedule for heating coil control loop.

Ladder Diagram

There are no relays or switches shown on the heating coil controls that would appear on a ladder diagram. This control system is designed to fail to full heat, therefore interlocks to devices such as time clocks and supply fans are not used.

Sequence of Operation

Hot deck temperature controller TC-XX-03, with its temperature transmitter TT-XX-05 in the heating coil discharge, modulates hot deck heating coil valve VLV-XX-02 to maintain supply air temperature setpoint. Controller TC-XX-04 with temperature transmitter TT-XX-02 in the outside air raises the setpoint of controller TC-XX-03 on a fall in outside air temperature and lowers it on a rise in outside air temperature.

Equipment Schedule

Figure 27 shows an equipment schedule for the heating coil control loop with setpoint reset.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
HOT DECK AIR TEMPERATURE	VLV-XX-02	HEATING COIL VALVE	----	3 - 15 PSIG	Cv = _ CLOSE AGAINST _ PSIG
	TC-XX-03	HOT DECK TEMPERATURE CONTROLLER	OA TEMP = 0 DEG F, HOT DECK = 120 DEG F OA TEMP = 60 DEG F, HOT DECK = 90 DEG F	PV = 40 TO 140 DEG F CPA = 90 TO 120 DEG F	CPA LO-LIMIT = 90 DEG F CPA HI-LIMIT = 120 DEG F
	TC-XX-04	OUTSIDE AIR TEMPERATURE CONTROLLER	SETPOINT = 30 DEG F PROPORTIONAL BAND = 37.5% MANUAL RESET = 50%	-30 TO +130 DEG F	----
	TT-XX-05	HOT DECK TEMPERATURE TRANSMITTER	----	40 TO 140 DEG F	----
	TT-XX-02	OUTSIDE AIR TEMPERATURE TRANSMITTER	----	-30 TO +130 DEG F	----

Figure 27. Equipment schedule for heating coil loop with setpoint reset.

<u>Equipment Schedule Information</u>

- VLV-XX02 Valve flow coefficient (Cv) is important replacement ordering information.
- TC-XX03 AI2 setpoints, low limit 90 °F, 120 °F.
- TC-XX03 range 40 to 140 °F.
- TC-XX03 PB = 25% and I = 60 seconds.
- TC-XX04 setpoint, 30 °F.
- TC-XX04 range -30 to 130 °F (must be the same as TT-XX02).
- TC-XX04 PB value, 37.5%.
- TT-XX02 range, -30 to 130 °F.
- TT-XX05 range, 40 to 140 °F.

<u>Outside Air Temperature (Setpoint Reset) TC-XX04 Controller Configuration Parameters.</u>

The **<u>setpoint</u>** is selected to be at the midpoint of the outside air temperature as shown in the reset schedule, which is 0 °F to 60 °F. (Figure 27). Therefore the setpoint is 30 °F.

In the example shown in the reset schedule (Figure 27), the outside air controller proportional band is selected so that as the outside air temperature changes from 0 to 60 °F (**throttling range**, TR), the controller output changes full-scale from 20 to 4 mA. This signal is sent to the CPA input of the HW controller shown in Figure 22. With a TR of 0 to 60 °F and an OA temperature transmitter sensor span of -30 to 130 °F, the OA controller proportional band is calculated:

PB = TR / (OA sensor span) x 100

= 60 °F / (130 °F - -30 °F) x 100

= 60 °F / (130 °F + 30 °F) x 100

= 60 °F / 160 °F x 100

= 37.5 %

<u>Supply Air Temperature Controller Configuration Parameters</u>

The heating coil controller **setpoint** is reset via CPA or Analog Input 2 (AI2). The low and high setpoints for AI2 are 90 and 120 °F, as found on the reset schedule Figure 27. The process variable **low and low ranges** are set to match the temperature transmitter (TT) range. Typical settings in a heating coil application are; low range = 40 °F and high range = 140 °F. The percent **proportional band** (PB) depends on the throttling range. A typical **throttling range** (TR) for the heating coil loop is 25 °F. With a temperature transmitter range (sensor span) of 40 to 140 °F the proportional band is:

$$\begin{aligned} PB &= TR / (\text{sensor span}) \times 100 \\ &= 25\ °F / (140\ °F - 40\ °F) \times 100 \\ &= 25\ °F / (\ 100\ °F\ ) \times 100 \\ &= 25.0\% \end{aligned}$$

Figure 28 shows the configuration checksheet for the outside air temperature controller.

Heating Hot Water Control Loop with Setpoint Reset

Figure 29 shows the hot water control loop with setpoint reset.

Control Schematic Information

- TC-XX01 is reverse acting, REV
- TC-XX01 has a contact on line 5 of the ladder diagram
- TT-XX01 is the PV input to TC-XX01
- TC-XX02 is direct acting, DIR
- TT-XX02 is the PV input to TC-XX02
- TC-XX01 output is the CPA input to TC-XX02
- VLV-XX01 is normally open NO from the boiler to the HW supply

OUTSIDE AIR TEMPERATURE CONTROLLER
(for heating coil setpoint reset)
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Rev (direct or reverse)
Setpoint Derived from	SPF	Panel (panel or AI2)
Low limit of setpoint	SPLL	-30 (adjustment lo range)
High limit of setpoint	SPHL	130 (adjustment hi range)
Setpoint	SP–	30 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	Dis
Digital Input 2	dI2-	Dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	130
Alarm 1 Hysteresis	Hys1	0 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	130
Alarm 2 Hysteresis	Hys2	0 (deadband)
Proportional band	P---	37.5 %
Integral value	I---	0 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	-30 (sensor/TT range)
Process Variable (PV) High Range	HI1-	130 (sensor/TT range)

Figure 28. Outside air temperature controller (for heating coil setpoint reset) configuration checksheet.

HEATING COIL CONTROLLER
(with setpoint reset)
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action		Act _Dir_ (direct or reverse)
Setpoint Derived from	SPF	_AI2_ (panel or AI2)
Low limit of setpoint	SPLL	_40_ (adjustment lo range)
High limit of setpoint	SPHL	_140_ (adjustment hi range)
Calibration for AI2	CAL2	_2-pt_
Low limit	Lo2-	_90_ (at 4mA input signal)
High limit	HL2-	_120_ (at 20 mA input signal)
Action for AO2	Ao-2	_rstp_ (2nd output)
Manual reset value	rStP	_12_ mA
Minimum controller output	AoLL	_4_ mA
Maximum controller output	AoHL	_20_ mA
Digital Input 1	dI1-	_Dis_
Digital Input 2	dI2-	_Dis_
Alarm 1 Action	AL1-	_HI_
Alarm 1 Type	AL1t	_Abs_
Alarm 1 Offset or Setpoint	oFF1 or AL1u	_140_
Alarm 1 Hysteresis	Hys1	_2_ (deadband)
Alarm 2 Action	AL2-	_HI_
Alarm 2 Type	AL2t	_Abs_
Alarm 2 Offset or Setpoint	oFF2 or AL1u	_140_
Alarm 2 Hysteresis	Hys2	_2_ (deadband)
Proportional band	P---	_25_ %
Integral value	I---	_60_ seconds
Derivative	d---	_0_ seconds
Process Variable (PV) Low Range	Lo1-	_40_ (sensor/TT range)
Process Variable (PV) High Range	HI1-	_140_ (sensor/TT range)

Figure 28. (Cont'd).

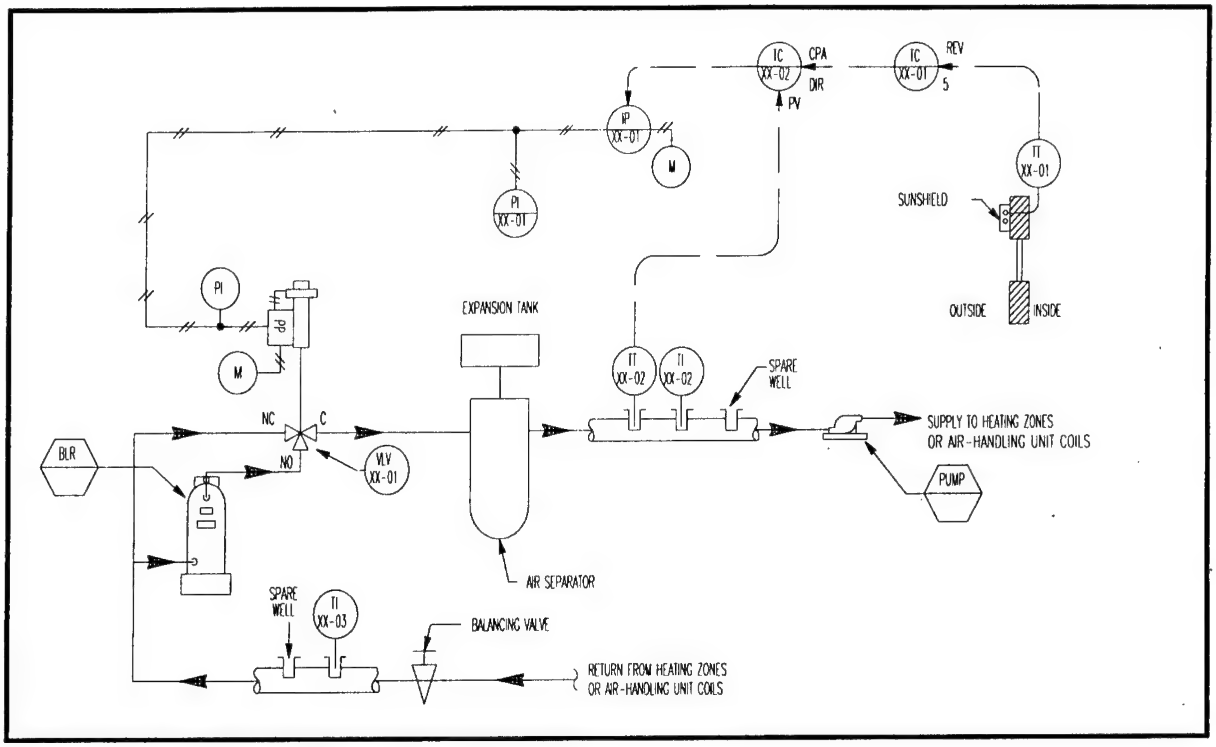


Figure 29. Hot water control loop with setpoint reset.

Reset Schedule Information

TC-XX04 throttling range is 60 °F (0 to 60 °F)

TC-XX03 low limit of setpoint is 100 °F, and high limit of setpoint 180 °F

TC-XX03 calibration values for AI2 setpoint are low limit 100 °F, high limit 180 °F

Figure 30 shows the reset schedule for the heating hot water supply.

Ladder Diagram
<u>Information from Ladder Diagram</u>

Figure 31 shows the ladder diagram primary pumping system with hot water reset.

- Line 5 shows the normally closed, NC, process variable (PV) contact of TC-XX01
- TC-XX01 PV contact controls R-XX04 on line 5, R-XX05 on line 6, PL-XX02 on line 7 and R-XX06 on line 8.
- R-XX04 normally open (NO) contact is in the pump starter diagram on line 103

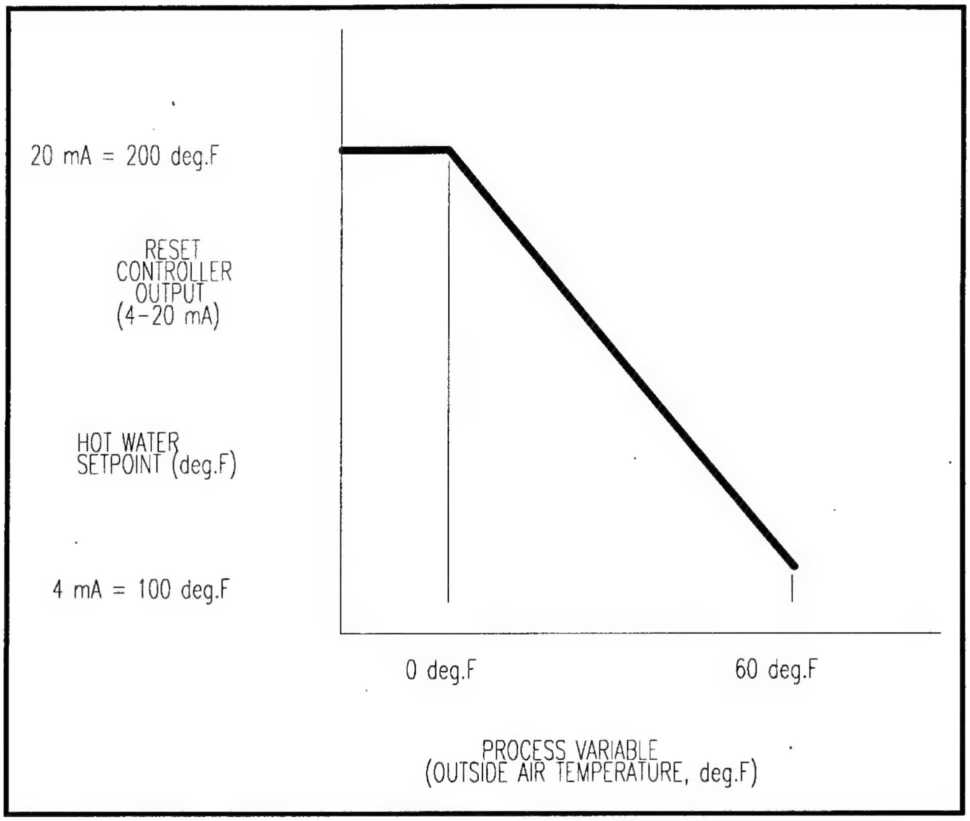


Figure 30. Reset schedule for the heating hot water supply.

- R-XX05 normally open (NO) contact is in the secondary pump starter diagram on line 204

- PL-XX02 illuminates indicating Heating at the control panel

- R-XX06 normally open (NO) contact is in the boiler starter diagram line 300

<u>Sequence of Operation for Primary Pumping System</u>

1. Outside air temperature transmitter TT-XX-01 signals outdoor air temperature to temperature controller TC-XX-01. On a fall in outside air temperature to 16 °C (60 °F), the process variable (PV) contacts of TC-XX-01 close to energize relays R-XX-04, R-XX-05, and R-XX-06 and pilot light PL-XX-02. The contacts of relay R-XX-04 energize the primary hot water pump, the contacts of relay R-XX-05 enable the secondary pumps, and the contacts of relay R-XX-06 enable the boiler control circuit.
2. On a rise in outside air temperature to 17 °C (62 °F), the PV contacts of controller TC-XX-01 open to de-energize relays R-XX-04 to stop the primary pump, to de-energize relay R-XX-05 to stop both secondary pumps, and to de-energize relay R-XX-06 to disable the boiler control circuit and to turn off pilot light PL-XX-02.

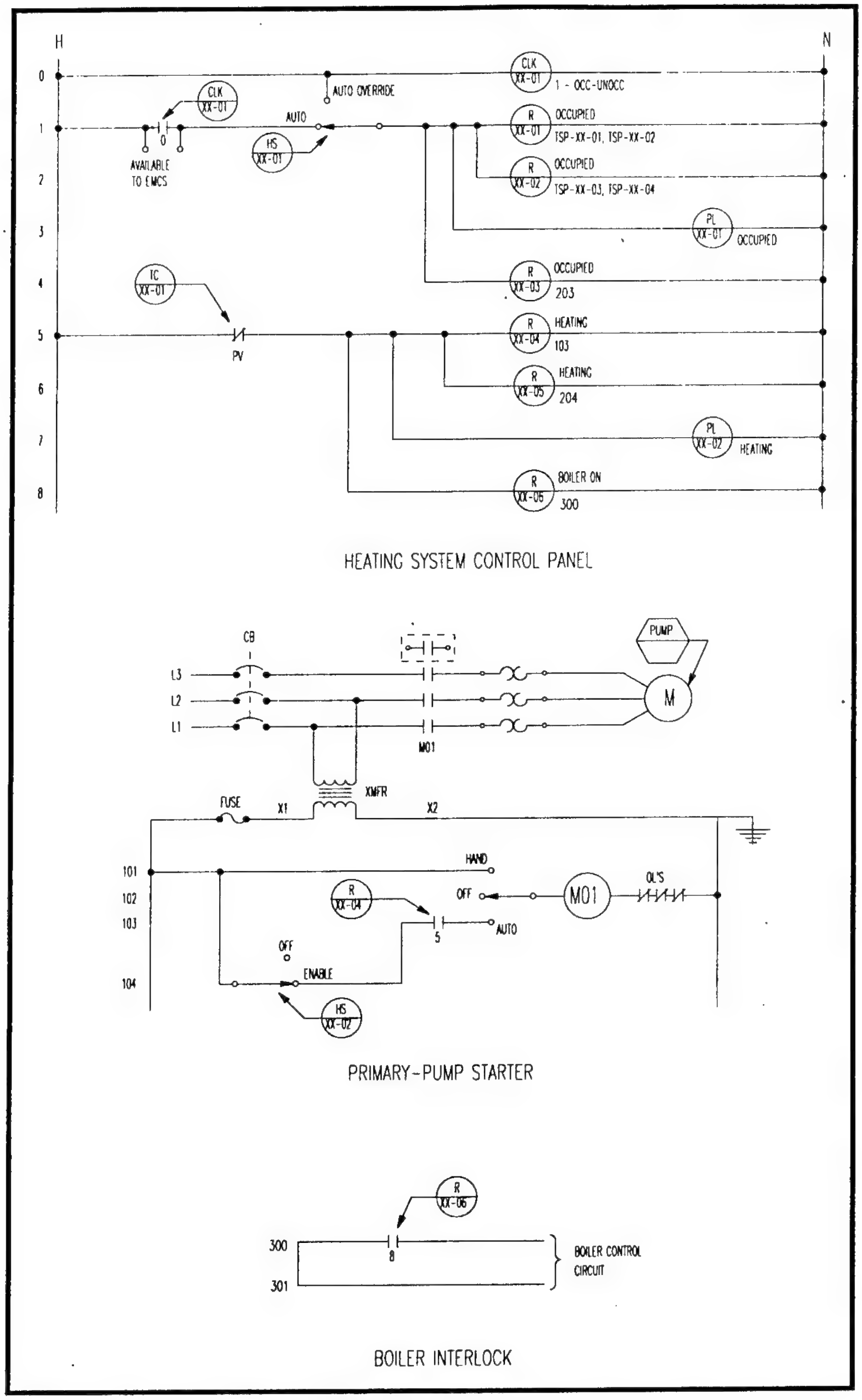


Figure 31. Ladder diagram primary pumping system with hot water reset.

3. Controller TC-XX-01 raises the setpoint of primary hot water supply temperature controller TC-XX-02 as the outside air temperature falls, and lowers the setpoint as the outside air temperature rises.
4. Temperature transmitter TT-XX-02 transmits the primary hot water supply temperature to temperature controller TC-XX-02, which then maintains its set-point by varying its signal to current-to-pneumatic transducer IP-XX-01. The

pneumatic signal from IP-XX-01 modulates primary hot water valve VLV-XX-01 to mix boiler water and primary return water to maintain the primary supply water temperature setpoint of controller TC-XX-02.

Equipment Schedule

Figure 32 shows the heating hot water equipment schedule.

Equipment Schedule Information

- VLV-XX01 Valve flow coefficient (Cv) is important replacement ordering information.
- TC-XX01 Setpoint 37.5 °F, PB value 37.5%, range -30 to 130 °F, PV contact closed below 60 °F and open above 62 °F.
- TC-XX02 low setpoint 70 °F and high setpoint 170 °F, PB value 15%, I value 60 SEC, Range 40 to 240 °F.
- TT-XX01 range -30 to 130 °F.
- TT-XX02 range 40 to 140 °F.

Configuration Parameters

HW Temperature Controller (with Setpoint Reset) Configuration Parameters

A sample configuration checksheet for a HW controller (using setpoint reset – see Figure 33) and a description of the most important configuration parameters follows. The controller is **direct acting** (DIR) with the control valve normally open. The heating coil controller **setpoint** must be configured as a remote setpoint (CPA) so that the controller recognizes that its setpoint is to be adjusted from an external signal, instead of from the front panel or the controller keypad.

Figure 32. Heating hot water equipment schedule.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
HOT WATER SUPPLY TEMPERATURE	VLV-XX-01	SYSTEM VALVE	——	3 - 15 PSIG	Cv = 20 CLOSE AGAINST 10 PSIG
	TC-XX-01	OUTSIDE-AIR TEMPERATURE CONTROLLER	30 DEG F PROPORTIONAL BAND 37.5% MANUAL RESET 50%	-30 TO +130 DEG F	PV CONTACT STARTS PUMP AT 60 DEG F STOPS PUMP AT 62 DEG F
	TC-XX-02	SYSTEM-SUPPLY TEMPERATURE CONTROLLER	OA TEMP = 0 DEG F, HWS TEMP = 200 DEG F OA TEMP = 60 DEG F, HWS TEMP = 100 DEG F	PV = 100 TO 250 DEG F CPA = 100 TO 200 DEG F	CPA LO-LIMIT = 100 DEG F CPA HI-LIMIT = 200 DEG F
	TT-XX-01	OUTSIDE-AIR TEMPERATURE TRANSMITTER	——	-30 TO +130 DEG F	——
	TT-XX-02	SYSTEM-SUPPLY TEMPERATURE TRANSMITTER	——	100 TO 250 DEG F	——

HEATING HOT WATER CONTROLLER
(with setpoint reset)
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action		Act Dir (direct or reverse)
Setpoint Derived from	SPF	AI2 (panel or AI2)
Low limit of setpoint	SPLL	40 (adjustment lo range)
High limit of setpoint	SPHL	240 (adjustment hi range)
Calibration for AI2	CAL2	2-pt
Low limit	Lo2-	70 (at 4mA input signal)
High limit	HL2-	170 (at 20 mA input signal)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	Dis
Digital Input 2	dI2-	Dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	240
Alarm 1 Hysteresis	Hys1	0 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	240
Alarm 2 Hysteresis	Hys2	0 (deadband)
Proportional band	P---	15 %
Integral value	I---	60 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	40 (sensor/TT range)
Process Variable (PV) High Range	HI1-	240 (sensor/TT range)

Figure 33. Heating hot water controller (with setpoint reset) configuration checksheet.

OUTSIDE AIR TEMPERATURE CONTROLLER
(for HW setpoint reset)
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action		Act rev (direct or reverse)
Setpoint Derived from	SPF	panel (panel or AI2)
Low limit of setpoint	SPLL	-30 (adjustment lo range)
High limit of setpoint	SPHL	130 (adjustment hi range)
Setpoint	SP -	30 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dis
Digital Input 2	dI2-	dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	62
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	130
Alarm 2 Hysteresis	Hys2	0 (deadband)
Proportional band	P---	37.5 %
Integral value	I---	0 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	-30 (sensor/TT range)
Process Variable (PV) High Range	HI1-	130 (sensor/TT range)

Figure 33. (Cont'd).

The **low and high limits of setpoint** are set to match the reset schedule (70 °F and 170 °F shown in Figure 27). These values can also be found in the *Equipment Schedule* drawing. Note that the **low and high limits of setpoint** set lower and upper limits on the setpoint so that it will not drop below or rise above these limits. The setpoint (calibration) input range **low limit and high limit** are also set to match the reset schedule (70 °F and 170 °F). These parameters scale the 4 to 20 mA CPA input signal so that the controller recognizes 4 mA as 70 °F and 20 mA as 170 °F. The **process variable high and low ranges** are set to match the temperature transmitter (TT) range. Typical settings in a heating HW application are; low range = 40 °F and high range = 240 °F. The percent **proportional band** (PB) depends on the throttling range. A typical **throttling range** (TR) for the heating HW loop is 30 °F. With a temperature transmitter range (sensor span) of 40 to 240 °F, the proportional band is:

$$
\begin{aligned}
PB &= TR / \text{sensor span} \times 100 \\
&= 30\ °F / (240\ °F - 40\ °F) \times 100 \\
&= 30\ °F / 200\ °F \times 100 \\
&= 15\%
\end{aligned}
$$

A typical **integral** (I) time is 60 seconds. The **derivative** (D) should ordinarily be set to 0.

The **alarm contact** output terminals on the back of this controller ordinarily are not wired to anything. To avoid confusion, the alarm setpoints should be set very high (240 °F) so that the alarm LED indicators on the front of the controller never light up.

Outside Air Temperature (Setpoint Reset) Controller Configuration Parameters

A sample configuration checksheet for the outside air temperature controller and a description of the most important configuration parameters follows: The controller is **reverse acting** (REV) so that as the outside air temperature rises, the output drops. The **setpoint** is configured as a local setpoint so that it can be adjusted from the controller keypad (or panel). The **<u>setpoint</u>** is selected to be at the midpoint of the outside air temperatures of 0 to 60 °F as shown in the reset schedule (Figure 27). Therefore the setpoint at mid point is 30 °F.

With the setpoint at midpoint of the TR, the **manual reset** value is also selected to be at midpoint (50 percent or 12 mA) of the TR. The **minimum and maximum controller outputs** are set to 4 and 20 mA, respectively. With some con-

trollers this may be defined as 0 and 100 percent output, respectively. The minimum and maximum output range ensures that the outside air controller output changes full range to correspondingly adjust the HW controller setpoint over its full 70 to 170 °F range as defined by the reset schedule in Figure 27.

The **process variable low and high ranges** are set to match the temperature transmitter (TT) sensor span. Typical settings in an outside air controller application are; low range = -30 °F and high range = 130 °F.

The **proportional band (PB)** instructs the controller to change its output in proportion to its input. In our example shown in the reset schedule Figure 27, the outside air controller proportional band is selected so that as the outside air temperature changes from 0 to 60 °F (also called the **throttling range**, TR), the controller output changes full-scale from 20 to 4 mA. This signal is sent to the CPA input of the HW controller shown in Figure 27, changing its setpoint from 120 to 90 °F. With a TR of 0 to 60 °F and an OA temperature transmitter sensor span of -30 to 130 °F, the OA controller proportional band is calculated:

$$
\begin{aligned}
PB &= TR / (\text{OA sensor span}) \times 100 \\
&= 60\ °F / (130\ °F - -30\ °F) \times 100 \\
&= 60\ °F / (130\ °F + 30\ °F) \times 100 \\
&= 60\ °F / 160\ °F \times 100 \\
&= 37.5\ \%
\end{aligned}
$$

The **integral** (I) time is set to 0 (zero) seconds or to “off.” The **derivative** (D) should also be set to 0.

The NC **alarm** contact output terminals on the back of this controller are usually wired to the HW pump motor starter to start and stop the pump based on outside air temperature. The controller contacts should be wired as normally closed (as a failsafe). The **alarm action** should be set as a high alarm. The **alarm type** should be set as an absolute or process variable alarm. The **alarm setpoint** is usually set at 60 °F to start the pump when the OA temperature drops below this temperature. The hysteresis or deadband should be set at 2 °F.

Setpoint Reset Control Loop Troubleshooting

Symptom: Hot water or coil discharge air temperature too hot or cold

Check Control Panel:

Indicator Lamps:

Is Fan Operating? (Enable, Auto, Occupied, HOA)

Hot Water/Coil Temp Controller

Is setpoint correct (per reset schedule)?

Is PV Input correct? (Calibrate TT)

Are configuration parameters correct? (Direct Action, PV high and low range, remote setpoint, PB)

Is controller output correct? Does HW valve modulate?

Outdoor Air Reset controller?

Does it call for Heat?

Are configuration parameters correct? (Reverse Action, Setpoint, Alarm Action, Alarm Setpoint, PV High and Low ranges, PB)

Is PV Input Correct? (Outside Air Temp) Calibrate TT.

Is Output Correct?

Economizer/Mixed Air Controller

System should not be in economizer mode when there is a call for heat.

Check OA damper. It should be in the minimum position.

Check Hydronic System:

Is pump operating? Is the delta P correct? Strainers Clean?

Is the boiler operating? At the correct temp? (Typically 180 °F)

Are HWS (180 °F or Temp per reset schedule) and HWR temps reasonable?

Secondary Hot Water Control System

Figure 34 shows the secondary hot water control loop.

Control Schematic Information

- TC-XX03 is direct acting, DIR.
- TT-XX03 is the PV input to TC-XX03.
- TSP-XX01 is the CPA input to TC-XX03 when R-XX01 is energized.
- TSP-XX02 is the CPA input to TC-XX03 when R-XX01 is not energized.
- R-XX01 is on line 1 of the secondary pump ladder diagram.
- VLV-XX02 is normally open, NO, to the primary HW supply.
- TSL-XX01 is on line 204 of the secondary pump ladder diagram.
- TSL-XX01, TT-XX03, and TSP-XX01 are located in the occupied space, LOC: XXXX.

Secondary Pump Starter Ladder Diagram.

Figure 35 shows a secondary pump starter ladder diagram.

Secondary Pumping System Ladder Diagram Information

- R-XX01 on line 1 of is controlled by the CLK-XX01 occupied/unoccupied contact on line 0.
- R-XX03 on line 4 is controlled by CLK-XX01 occupied contact on line 1.
- R-XX03 NO contact on line 203 is controlled by R-XX03 on line 4.
- R-XX05 on line 204 is controlled by the PV contact of TC-XX01 on line 5.
- TSL-XX01 NO contact is controlled by TSL-XX01 in the controlled space.

Secondary Heating System Sequence of Operation

1. Temperature transmitter TT-XX-03 signals the zone space temperature to controller TC-XX-03, which then maintains its setpoint by varying its current output signal to transducer IP-XX-02. The pneumatic signal from IP-XX-02 modulates secondary zone control valve VLV-XX-02. Zone control valve VLV-XX-02 mixes primary supply water with secondary return water to maintain the zone space temperature setpoint. The temperature control loop for the other secondary zone functions identically.

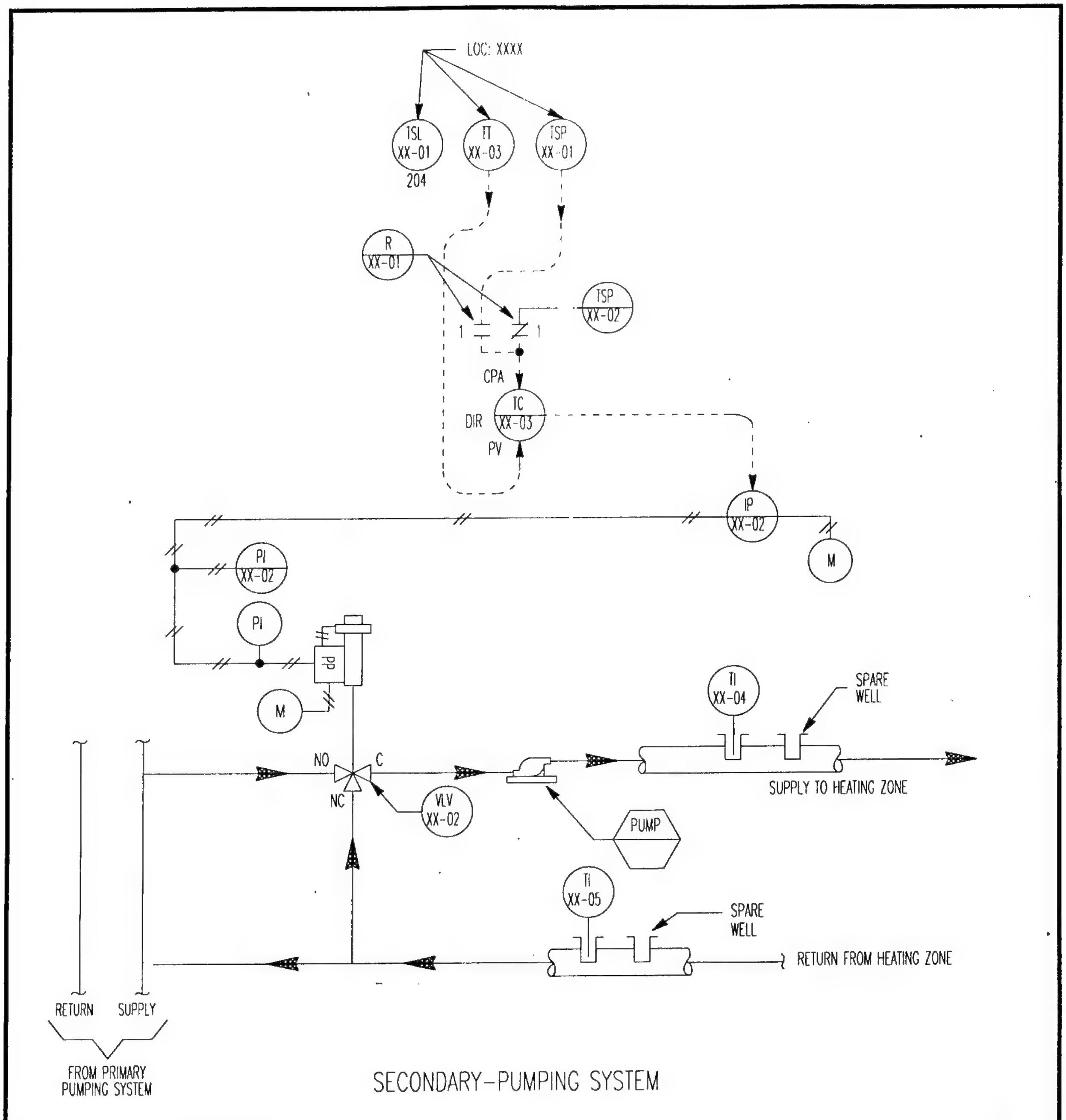


Figure 34. Secondary hot water control schematic.

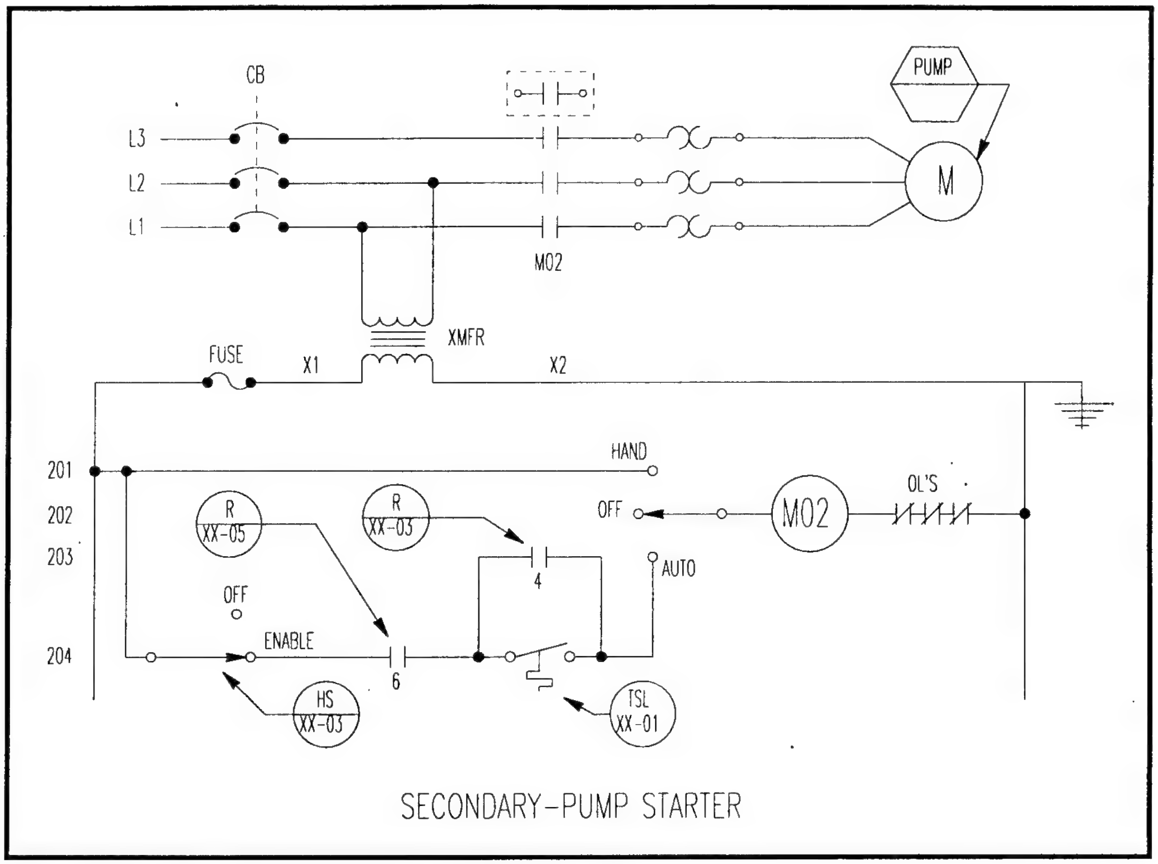


Figure 35. Secondary pumping system ladder diagram.

2. Throughout the occupied mode, the contacts of time clock CLK-XX-01 are closed to energize relays R-XX-01, R-XX-02, and R-XX-03, and to turn on pilot light PL-XX-01. The contacts of relay R-XX-01 connect temperature setpoint device TSP-XX-01 to allow manual adjustment of the setpoint of temperature controller TC-XX-03. Relay R-XX-02 provides the same function for TSP-XX-03 in adjustment of controller TC-XX-04. Relay R-XX-03 closes contacts in the starter control circuits of the secondary pumps. The secondary system pumps will start whenever the contacts of relay R-XX-03 (occupied) and R-XX-05 (heating) are closed in their respective pump starter circuits.
3. During the unoccupied mode, the contacts of time clock CLK-XX-01 are open, de-energizing relays R-XX-01, R-XX-02, and R-XX-03, and pilot light PL-XX-01 turns off. The transfer of the contacts of relay R-XX-01 transfer temperature setpoint adjustment of TC-XX-03 from TSP-XX-01 to TSP-XX-02; likewise, relay R-XX-02 transfers temperature setpoint adjustment of TC-XX-04 from TSP-XX-03 to TSP-XX-04. The contacts of relay R-XX-03 open the secondary pump starter circuits to place the secondary pumps under the respective night thermostats TSL-XX-01 and TSL-XX-02. When the zone space temperature falls to 13 °C (55 °F), the zone's secondary pump is energized and remains energized until the temperature rises to 14 °C (57 °F).

Equipment Schedule

Figure 36 shows an equipment schedule for the secondary pumping system.

Equipment Schedule Information

- TT-XX03 range is 50 to 85 °F.
- VLV-XX02 Valve flow coefficient (Cv) is important replacement ordering information.
- TC-XX03 setpoint is adjustable form 50 to 85 °F, the setpoint adjustment to the occupants is limited to 66 to 73 °F.
- TSP-XX01 has a range of 50 to 85 °F, and it is available to the occupants.
- TSP-XX02 has a range of 50 to 85 °F, it is set to adjust the setpoint to 57 °F.
- TSL-XX01 setpoint is 55 °F. It starts the secondary pump at 55 and shuts it of at 57.

Space Temperature Controller with Setpoint Reset Configuration Parameters

The space temperature controller has its setpoint adjusted by either TSP-XX01 during the occupied mode, or TSP-XX02 during the unoccupied mode. The controller AI2 is set up to be adjusted over the 50 to 85 °F of the TSPs. However, the range of control can be limited by setting the setpoint low and high limits.

In this example the limits are from 66 to 72 °F. The proportional band needs to be set to control over 2 to 3 °F throttling range, or 5 to 8 percent PB. The integral is set to 300 seconds, and the derivative to 0 seconds. Figure 37 shows the space temperature controller configuration checksheet.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
SPACE TEMPERATURE	TT-XX-03	SPACE-TEMPERATURE TRANSMITTER	——	50 TO 85 DEG F	——
	VLV-XX-02	ZONE VALVE	——	3-15 PSIG	Cv = 7 CLOSE AGAINST 10 PSIG
	TC-XX-03	SPACE TEMPERATURE CONTROLLER	70 DEG F	50 TO 85 DEG F	SET LIMITS AVAILABLE TO OCCUPANT BY TSP-XX-01 AT 66 TO 72 DEG F
	TSP-XX-01	MANUAL SETPOINT ADJUSTMENT	4 mA = 50 DEG F 20 mA = 85 DEG F	——	AVAILABLE TO OCCUPANT
	TSP-XX-02	MANUAL SETPOINT ADJUSTMENT	57 DEG F	——	——
SPACE LOW-LIMIT TEMPERATURE	TSL-XX-01	SPACE LOW-LIMIT THERMOSTAT	55 DEG F	——	STARTS PUMP AT 55 DEG F STOPS PUMP AT 57 DEG F
OCCUPIED MODE	CLK-XX-01 CONTACT	365-DAY SCHEDULE	——	NORMAL SCHEDULE: M - F CONTACT CLOSED: 0700 HRS CONTACT OPEN: 1700 HRS	CONTACT OPEN: SAT, SUN

Figure 36. Equipment schedule for secondary pumping system.

Cooling Coil Control Loop

Figure 38 shows the ladder diagram for the cooling coil control.

Cooling Coil Control Schematic Information

- TC-XX02 is direct acting, DIR.
- TT-XX04 is an averaging sensor and is the PV input to TC-XX02.
- R-XX06 NO contact controls the output signal to IP-XX02, it is located on line 8 of the ladder diagram.
- VLV-XX01 is normally closed, NC, to the CW return.

Ladder Diagram

Figure 39 shows the ladder diagram for the cooling coil.

Cooling Coil Ladder Diagram Information

- R-XX06 on line 8 controls is in the control circuit to IP-XX02, it is controlled by R-XX01 on line 1 and MO1 NO contact on line 7.
- R-XX01 NO contact on line 8 is controlled by CLK-XX01 NO occupied contact on line 1
- MO1 NO Auxiliary Contact is controlled by MO1 on line 102.

Sequence of Operation

Temperature transmitter TT-XX-04 signals the cold duct discharge temperature to temperature controller TC-XX-02. During the ventilation delay and occupied modes, relay R-XX-06 is energized and its contacts close, allowing the TC-XX-02 signal to be received by current-to-pneumatic transducer IP-XX-02. The pneumatic output of IP-XX-02 modulates cooling coil valve VLV-XX-01 to maintain the setpoint of controller TC-XX-02. During the unoccupied mode, the contacts of relay R-XX-06 are open, cooling coil valve control is interrupted, and the valve closes.

Equipment Schedule

Figure 40 shows the cooling coil equipment schedule.

Equipment Schedule Information

- VLV-XX01 Valve flow coefficient (Cv) is important replacement ordering information.
- TC-XX02 setpoint is 57 °F, it has a range of 40 to 140 °F.
- TT-XX04 has a range of 40 to 140 °F.

SPACE TEMP CONTROLLER
(with setpoint reset)
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Dir (direct or reverse)
Setpoint Derived from	SPF	AI2 (panel or AI2)
Low limit of setpoint	SPLL	66 (adjustment lo range)
High limit of setpoint	SPHL	72 (adjustment hi range)
Calibration for AI2	CAL2	2-pt
Low limit	Lo2-	50 (at 4mA input signal)
High limit	HL2-	85 (at 20Ma input signal)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	Dis
Digital Input 2	dI2-	Dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	85
Alarm 1 Hysteresis	Hys1	1 (deadband)
Alarm 2 Action	AL2-	85
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	85
Alarm 2 Hysteresis	Hys2	1 (deadband)
Proportional band	P---	5 %
Integral value	I---	300 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	50 (sensor/TT range)

Figure 37. Space temperature controller (with setpoint reset) configuration checksheet.

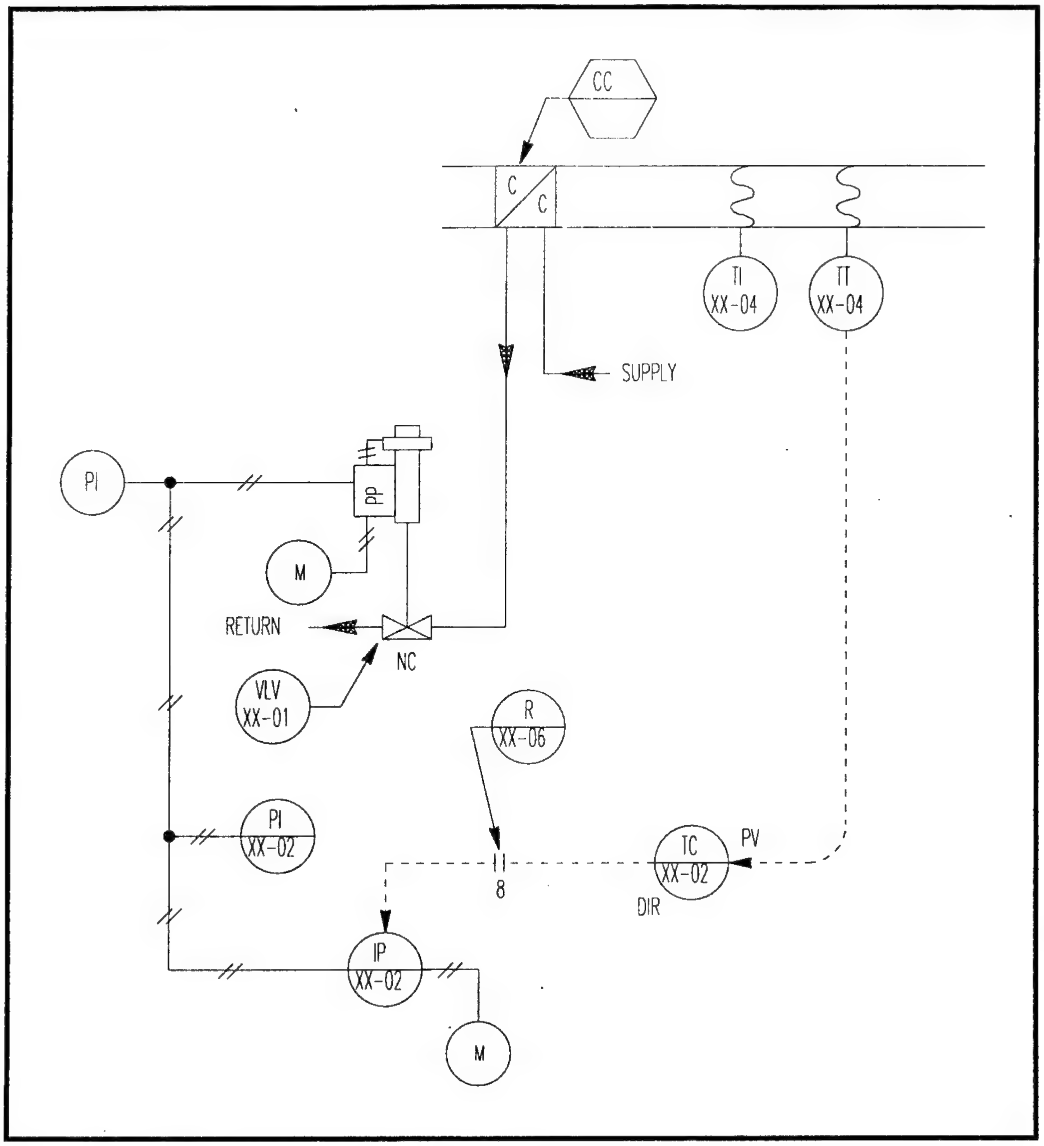


Figure 38. Cooling coil control ladder diagram.

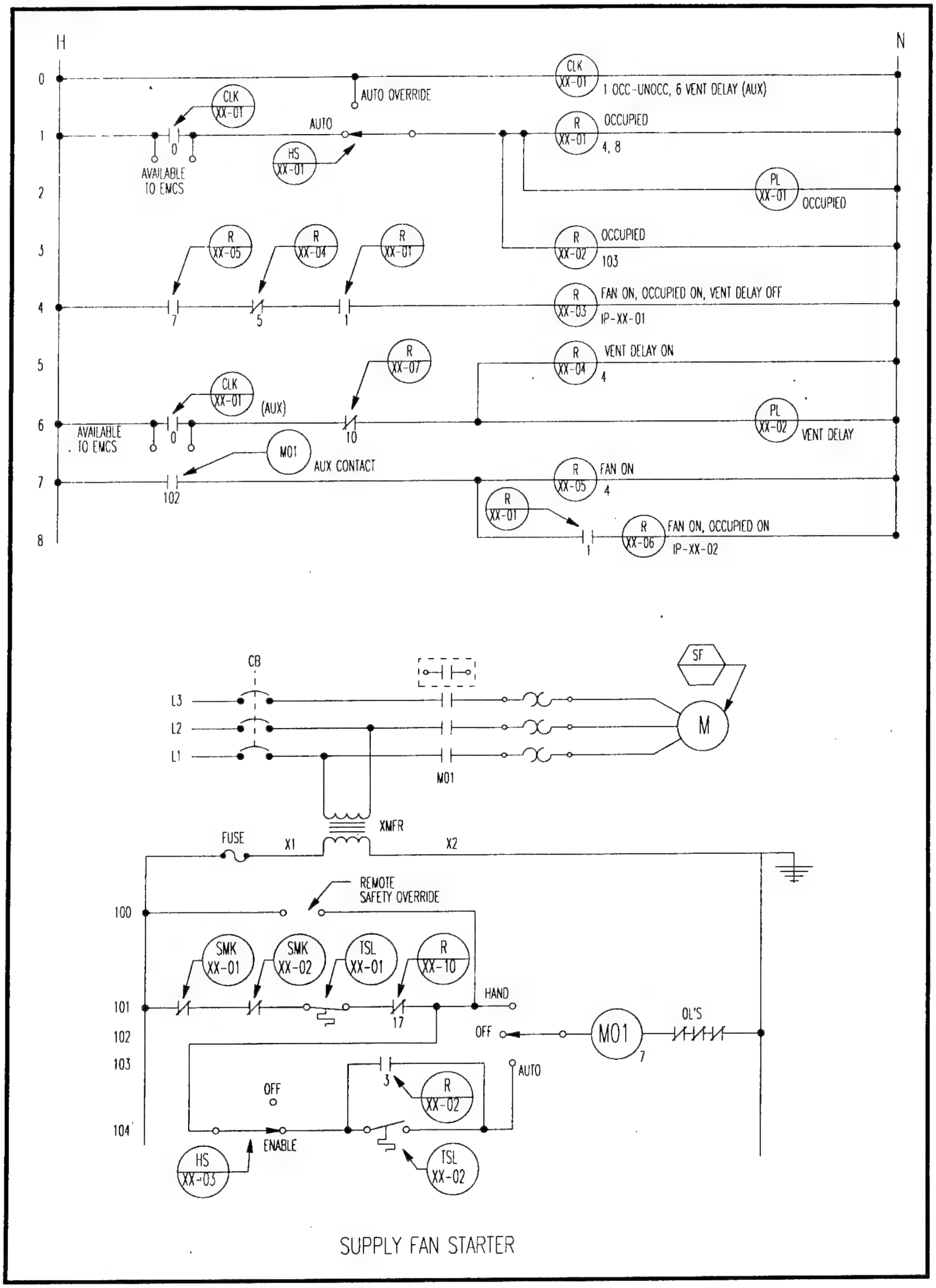


Figure 39. Cooling coil ladder diagram.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
COLD DUCT AIR TEMPERATURE	VLV-XX-01	COOLING COIL VALVE	—	3 - 15 PSIG	Cv = _ CLOSE AGAINST _ PSIG
	TC-XX-02	COLD DUCT TEMPERATURE CONTROLLER	57 DEG F	40 TO 140 DEG F	—
	TT-XX-04	COLD DUCT TEMPERATURE TRANSMITTER	—	40 TO 140 DEG F	—

Figure 40. Cooling coil equipment schedule.

Cooling Control Loop Configuration Parameters

The cooling coil controller is configured to be direct acting. The low and high setpoint limits are the same as the TT span 40 to 140 °F. A typical proportional band setting is 25 percent, with an integral of 60 seconds and a derivative of 0 seconds. A Typical setpoint would be 55 °F. Alarms are not used so they should be set to a high value to prevent the indicators on the front of the controller from illuminating. Figure 41 shows the checksheet for the cooling coil temperature control.

Cooling Coil Loop Troubleshooting

Symptom: Coil discharge air temperature too warm

Check Control Panel:

Indicator Lamps:

Is the fan running? (Check Enable, Auto, Occupied, and HOA switches)

Has a safety tripped? Does a pilot light indicate a system problem (freezestat, smoke, high static, economizer, etc)? Press the control panel "reset" button.

Cooling Coil Temperature Controller

Is the setpoint correct?

Is the PV Input correct? Compare to thermometer.

Are the configuration parameters correct? Check Direct Action, PV high and low range, PB)

Cooling Coil Temperature Control
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Dir (direct or reverse)
Setpoint Derived from	SPF	Panel (panel or AI2)
Low limit of setpoint	SPLL	40 (adjustment lo range)
High limit of setpoint	SPHL	140 (adjustment hi range)
Setpoint	SP–	55 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dis
Digital Input 2	dI2-	dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	140
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	140
Alarm 2 Hysteresis	Hys2	2 (deadband)
Proportional band	P---	25 %
Integral value	I---	60 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	40 (sensor/TT range)
Process Variable (PV) High Range	HI1-	140 (sensor/TT range)

Figure 41. Cooling coil temperature control configuration checksheet.

Is the controller output correct? Does the valve modulate?

Economizer/Mixed Air Controller

System may be in economizer mode when there is a call for cooling.

Is the OA damper at minimum position with the economizer is off?

Check Hydronic System:

Is the pump running?

Is the chiller operating? Is it operating at the correct temp (typically 45 °F)?

Is there a pressure drop across the coil? Are the strainers clean?

Are the CWS and CWR temperatures reasonable (10 °F differential across the coil)?

Economizer/Mixed Air Control Loop

Figure 42 shows the mixed air with economizer control loop.

Mixed Air with Economizer Control Loop Information

- EC-XX01 has no control action associated with it, it has two contacts on line 9 of the ladder diagram.
- TT-XX03 in the return air duct is the PV input to EC-XX01.
- TT-XX02 in the outside air duct is the CPA input to EC-XX01.
- TC-XX01 is direct acting, DIR.
- TT-XX01 in the mixed air duct is the PV input to TC-XX01.
- NO contact in the output circuit from TC-XX01 is controlled by R-XX07 on line 10 of the ladder diagram.
- TY-XX01 has input form TC-XX01 when NO contact of R-XX07 is closed, and from MPS-XX01.
- NO contact in the output circuit from TY-XX01 is controlled by R-XX03 on line 4 of the ladder diagram.
- AD-XX01 outside air damper and AD-XX03 relief air damper are NC, AD-XX02 return air damper is NO.

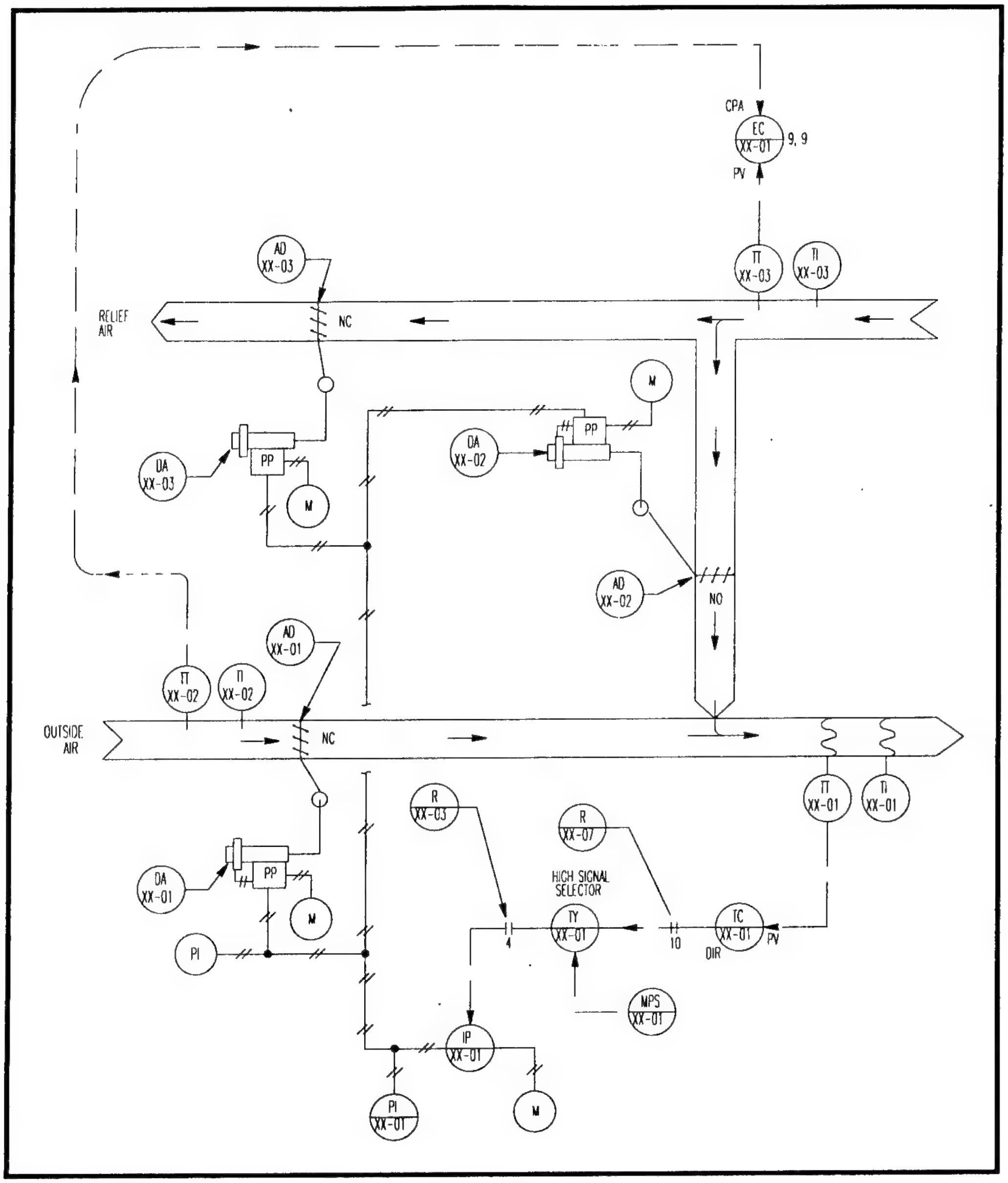


Figure 42. Mixed air with economizer control loop.

Mixed Air Economizer Ladder Diagram

Figure 43 shows the ladder diagram for the mixed air economizer control.

Mixed Air with Economizer Ladder Diagram Information

- EC-XX01 NO PV and DEV contacts are on line 9.
- PL-XX03 on line 9, ECONOMIZER indicator lamp is illuminated when PV and DEV contact both close.

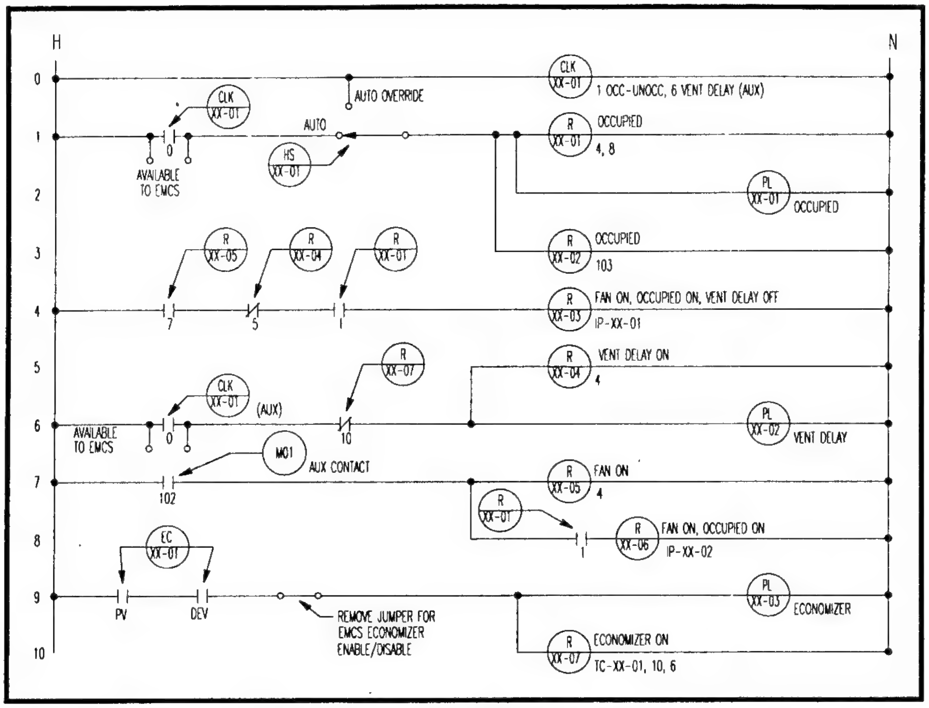


Figure 43. Mixed air economizer control ladder diagram.

- R-XX07 on line 10 is energized when PV and DEV contacts on line 9 both close, closing the NO contact in the output circuit of TC-XX01, and opening the NC contact on line 6.
- R-XX04 on line 5 is controlled by CLK-XX01, Vent Delay NO contact on line and R-XX07 NC contact on line 6, when either contact on line 6 is open R-XX04 NC contact on line 4 is closed.

Sequence of Operation

1. Time clock CLK-XX-01 has two independent sets of contacts, which between them determine the mode of system operation. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal from reaching current-to-pneumatic transducers IP-XX-01 and IP-XX-05. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.
2. When the time clock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05, and relay R-XX-07, and, with the contacts of relay R-XX-01, energize relay R-XX-06. One set of contacts of relay R-XX-05 energizes the return fan. The other set of contacts (line 4) is involved in the energizing of relay

R-XX-03 when the ventilation delay mode of operation is over. The contacts of relay R-XX-06 enable discharge temperature controller TC-XX-02 to control cooling coil valve VLV-XX-01. The contacts of relay R-XX-07 enable control of the inlet guide vanes on the supply and return fans. The outside air and relief air dampers remain closed and the return air damper remains open.

3. When the ventilation delay contacts of time clock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized and pilot light PL-XX-01 is turned off. The normally closed contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. One pair of normally open contacts of relay R-XX-03 connect the output of the minimum outside air flow controller FC-XX-02 to current-to-pneumatic transducer IP-XX-05, allowing modulation of the minimum outside air damper to maintain the flow at setpoint. The other pair of normally open contacts of relay R-XX-03 connect the output signal of the mixed air temperature controller TC-XX-01 to current-to-pneumatic transducer IP-XX-01, if the normally open contacts of relay R-XX-08 are also closed. Economizer EC-XX-01 controls the action of relay R-XX-08. The economizer receives signals from outside air temperature transmitter TT-XX-02 and from return air transmitter TT-XX-03. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-08 is energized and pilot light PL-XX-03 is turned on. When relays R-XX-03 and R-XX-08 are both energized, the output of mixed air controller TC-XX-01 is received by current-to-pneumatic transducer IP-XX-01 and the economizer outside air, relief air, and return air dampers are modulated to maintain the mixed air temperature controller setpoint.

Mixed Air With Economizer Equipment Schedule

Figure 44 shows the equipment schedule for the economizer/mixed air equipment.

Troubleshooting Economizer/Mixed Air Control Loop

Figure 45 shows the checksheet for the mixed air temperature controller.

Check Control Panel:

Indicator Lamps:

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
MIXED AIR TEMPERATURE	DA-XX-01 DA-XX-02 DA-XX-03	DAMPER ACTUATOR	—	(3 - 15 PSIG)	—
	MPS-XX-01	MINIMUM POSITION SWITCH	—	—	SET MIN OA _ CFM EQUAL TO _ CFM
	TC-XX-01	MIXED AIR TEMPERATURE CONTROLLER	(55 DEG F)	(40 TO 140 DEG F)	—
	TT-XX-01	MIXED AIR TEMPERATURE TRANSMITTER	—	(40 TO 140 DEG F)	—
	TT-XX-02	OUTSIDE AIR TEMPERATURE TRANSMITTER	—	(-30 TO +130 DEG F)	—
	TT-XX-03	RETURN AIR TEMPERATURE TRANSMITTER	—	(-30 TO +130 DEG F)	—
	EC-XX-01	ECONOMIZER CONTROLLER	PV CONTACT CLOSE AT _ DEG F OPEN AT _ DEG F	(-30 TO +130 DEG F)	DEV CONTACT CLOSE AT DELTA T = _ DEG F OPEN AT DELTA T = _ DEG F

Figure 44. Economizer/mixed air equipment schedule.

Is the fan running? (Check: Enable, Auto, Occupied, and HOA buttons)

Has a safety tripped? Does a pilot light indicate a system problem (freezestat, smoke, high static, economizer, etc)? Press the control panel "reset" button.

Economizer/Mixed Air Controller

PV and DEV contacts (Alarms) must both be energized for the Economizer to be "On."

Are the configuration parameters correct? (Direct Action, PV high and low range, remote setpoint, Alarm 1 (PV) type/action/setpoint, Alarm 2 (DEV) type/action/setpoint)

Mixed Air Temp Controller

Is the setpoint correct (typically 55 °F)?

Is the PV Input correct? Compare to thermometer.

Are the configuration parameters correct? (Check Direct Action, PV high and low range, PB.)

Is the controller output correct? Do the dampers modulate?

Is controller output correct? Do the dampers modulate with the economizer on?

Is the OA damper at minimum position with the economizer is off?

MIXED AIR TEMPERATURE CONTROLLER
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action		Act Dir (direct or reverse)
Setpoint Derived from	SPF	Panel (panel or AI2)
Low limit of setpoint	SPLL	40 (adjustment lo range)
High limit of setpoint	SPHL	140 (adjustment hi range)
Setpoint	SP--	55 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dis
Digital Input 2	dI2-	dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	140
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	Abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	140
Alarm 2 Hysteresis	Hys2	2 (deadband)
Proportional band	P---	10 %
Integral value	I---	60 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	40 (sensor/TT range)
Process Variable (PV) High Range	HI1-	140 (sensor/TT range)

Figure 45. Mixed air temperature controller.

ECONOMIZER CONTROLLER
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Dir (direct or reverse)
Setpoint Derived from	SPF	Panel (panel or AI2)
Low limit of setpoint	SPLL	-30 (adjustment lo range)
High limit of setpoint	SPHL	130 (adjustment hi range)
Calibration for AI2	CAL2	2-pt
Low limit	Lo2-	-30 (at 4mA input signal)
High limit	HL2-	130 (at 20 mA input signal)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dis
Digital Input 2	dI2-	dis
Alarm 1 Action	AL1-	HI
Alarm 1 Type	AL1t	Abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	73
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	HI
Alarm 2 Type	AL2t	dEv
Alarm 2 Offset or Setpoint	oFF2 or AL1u	10
Alarm 2 Hysteresis	Hys2	2 (deadband)
Proportional band	P---	0 %
Integral value	I---	0 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	-30 (sensor/TT range)
Process Variable (PV) High Range	HI1-	130 (sensor/TT range)

Figure 45. (Cont'd).

Supply Duct Static Pressure Control Loop

Figure 46 shows the supply duct static pressure control loop.

Supply Duct Static Pressure Control Schematic Information:

- PC-XX01 is reverse acting, REV.
- DPT-XX01 is the PV input to PC-XX01, it has a high pressure tap, H in the supply duct and a low pressure tap L, open to atmosphere.
- NO contact in the output circuit of PC-XX01 is controlled by R-XX07 on line 9 of the ladder diagram.
- IV are normally closed, NC.
- SMK-XX01 has contacts on lines 15 and 101 of the ladder diagram.
- DPS-XX02 has a contact on line 18 of the ladder diagram.
- TSL-XX01 has contacts on lines 13 and 101 of the ladder diagram.

Figures 47 and 48, respectively, show ladder diagrams for the VAV system, and the VAV system fan starter circuit.

Supply Duct Static Pressure Ladder Diagram Information

- R-XX07 on line 9 is controlled by MO1 NO Aux Contact on line 7.
- R-XX07 is in the control circuit to IP-XX03.

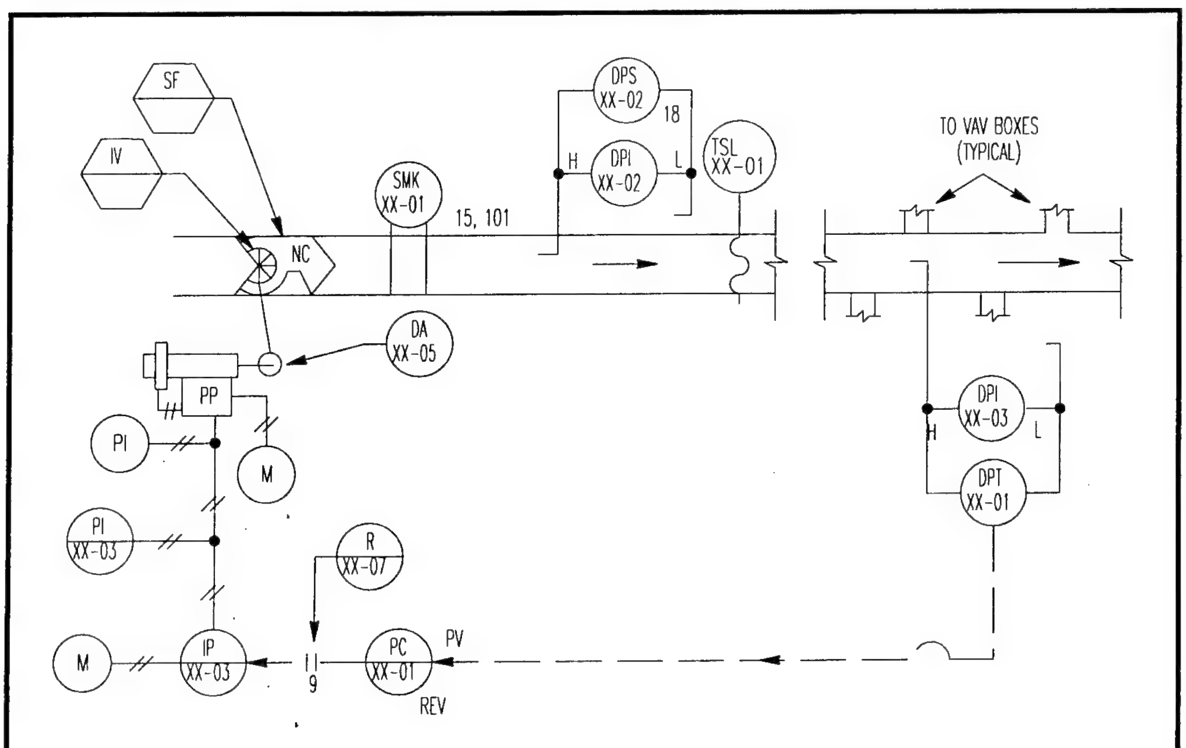


Figure 46. Supply duct static pressure control loop.

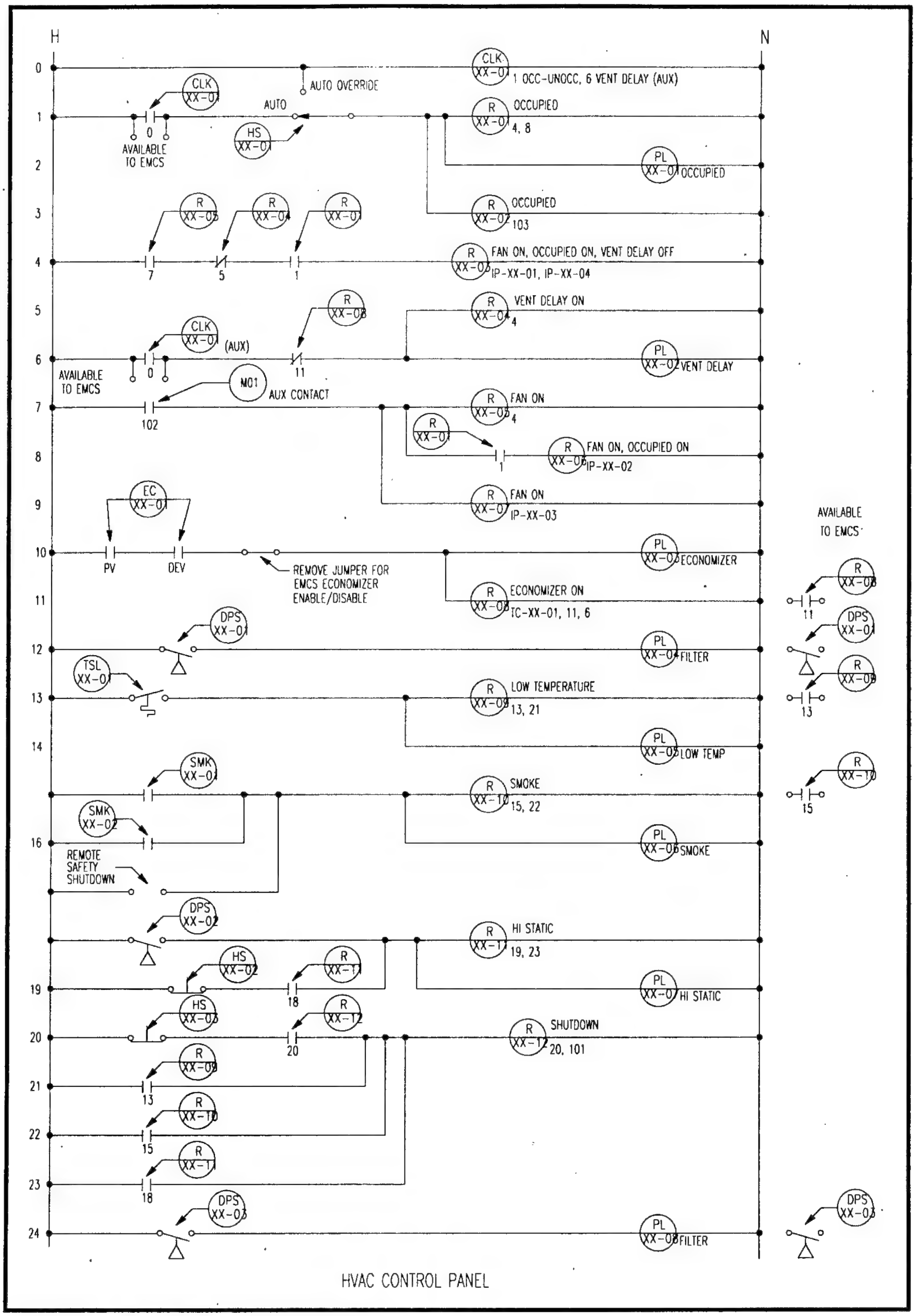


Figure 47. Ladder diagram for VAV system.

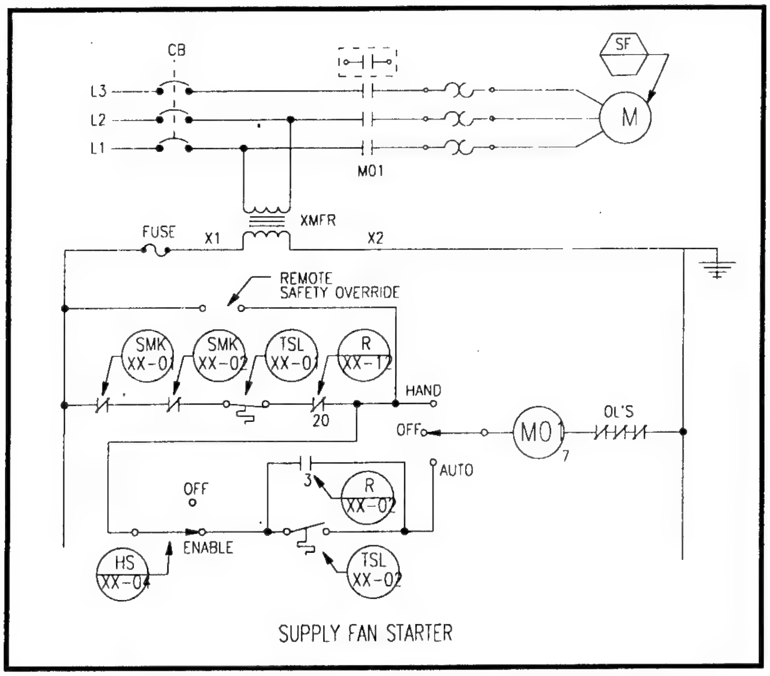


Figure 48. Ladder diagram for VAV system fan starter circuit.

Sequence of Operation

1. A pressure sensing element and transmitter DPT-XX-01 located in the supply duct (the location is determined by field conditions) signals duct static pressure to controller PC-XX-01. Whenever the supply fan runs, the auxiliary contacts of the fan starter energize relay R-XX-07. The output of pressure controller PC-XX-01 is sent, through the contacts of relay R-XX-07, to current-to-pneumatic transducer IP-XX-03.
   The pneumatic output of the transducer modulates the supply fan inlet vane actuator DA-XX-04 to maintain the pressure controller setpoint. When the fan is de-energized, relay R-XX-07 is de-energized, its contacts open, and the inlet vane dampers remain closed.
2. When the setpoint of high limit static pressure switch DPS-XX-02 in the supply fan discharge is exceeded, its contacts close, energizing relay R-XX-11 and lighting high-static pilot light PL-XX-07. One set of the contacts of relay R-XX-11 locks in relay R-XX-11, and another set of contacts energizes relays R-XX-12 and R-XX-13. One set of the contacts of relay R-XX-12 locks in relays R-XX-12 and R-XX-13, and the other set of contacts de-energizes the supply fan. The contacts of relay R-XX-13 de-energize the return fan. To restart the fans, manual switch HS-XX-02 must be momentarily depressed and then manual switch HS-XX-03 must be depressed.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
SUPPLY DUCT STATIC PRESSURE	DA-XX-05	SUPPLY FAN INLET VANE ACTUATOR	—	21 - 103 kPa (3-15 PSIG)	—
	PC-XX-01	SUPPLY DUCT STATIC PRESSURE CONTROLLER	300 kPa (1.2 INCHES WATER)	0 - 500 kPa (0.0 - 2.0 INCHES WATER)	—
	DPT-XX-01	SUPPLY DUCT STATIC PRESSURE TRANSMITTER	—	0 - 500 kPa (0.0 - 2.0 INCHES WATER)	—
	DPS-XX-02	SUPPLY DUCT - HIGH STATIC PRESSURE SAFETY	—	1000 - 1500 kPa (4.0 - 6.0 INCHES WATER)	—

Figure 49. Equipment schedule for VAV system.

Equipment Schedule

Figure 49 shows the equipment schedule for the VAV system.

Equipment Schedule Information

- DA-XX05 operates the supply fan inlet guide vanes over 3 - 15 psig.
- PC-XX02 has a setpoint of 1.2 in. wc, it is configured with a range of 0 - 2.0 in. wc.
- DPT-XX01 has a range of 0 to 2.0 in. wc.
- DPS-XX01 has a setpoint of ________.

Supply Duct Static Pressure Controller Configuration Parameters

Pressure controller PC-XX01 is configured as reverse acting. As the input signal from differential pressure transducer (DPT-XX01) increases above setpoint the output of PC-XX01 decreases closing the inlet vane guides to the supply fan. A typical static pressure setpoint is 1.0 inch water column (iwc). The low and high setpoint limits are 0 and 2 iwc. The DPT must have a relatively low range, such as 0.0 to 2.0 in. of iwc to have a good sensitivity to changes in static. High proportional values 200 to 300 percent are used for this control loop. Integral values should be 30 seconds or lower. Derivative should be set to 0 seconds. Figure 50 shows the configuration checksheet for the supply duct static pressure controller.

Duct Static Control Loop Troubleshooting

Various problems may occur in VAV systems that have return fans. Refer to the return fan control loop troubleshooting section.

Return Fan Flow Control Loop

Figure 51 shows the return fan control loop.

SUPPLY DUCT STATIC PRESSURE CONTROLLER
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	rEv (direct or reverse)
Setpoint Derived from	SPF	panel (panel or AI2)
Low limit of setpoint	SPLL	0.0 (adjustment lo range)
High limit of setpoint	SPHL	2.0 (adjustment hi range)
Setpoint	SP–	1.0 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dis
Digital Input 2	dI2-	dis
Alarm 1 Action	AL1-	hI
Alarm 1 Type	AL1t	abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	2.0
Alarm 1 Hysteresis	Hys1	0.2 (deadband)
Alarm 2 Action	AL2-	hI
Alarm 2 Type	AL2t	abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	2.0
Alarm 2 Hysteresis	Hys2	0.2 (deadband)
Proportional band	P---	200 %
Integral value	I---	30 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	0.0 (sensor/DPT range)
Process Variable (PV) High Range	HI1-	2.0 (sensor/DPT range)

Figure 50. Supply duct static pressure controller configuration checksheet.

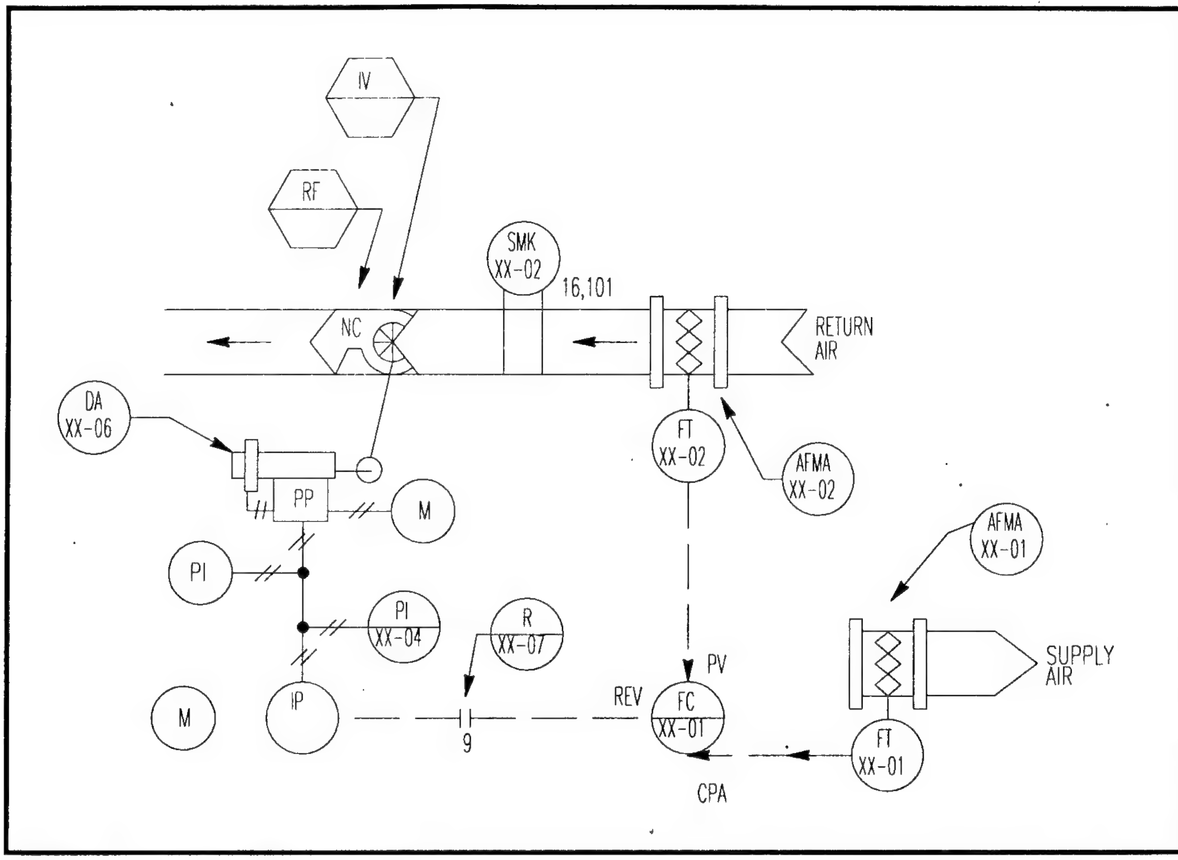


Figure 51. Return fan control loop.

Return Fan Control Loop Information

- FC-XX01 is reverse acting, REV.
- FT-XX02 is the PV input to FC-XX01.
- FT-XX01 is the CPA input to FC-XX01.
- NO contact in the control circuit to IP-XX04, is controlled by R-XX07 on line 9 of the ladder diagram.
- IV is normally closed, NC.
- SMK-XX02 has contacts on lines 16 and 101 of the ladder diagram.

Figures 52 and 53, respectively, show ladder diagrams for the return fan VAV control panel, and the return fan VAV motor starter.

Return Fan Ladder Diagram Information

- R-XX07 on line 9 is controlled by NO MO1 Aux Contact on line 7.
- R-XX07 has a contact in the control circuit to IP-XX03.

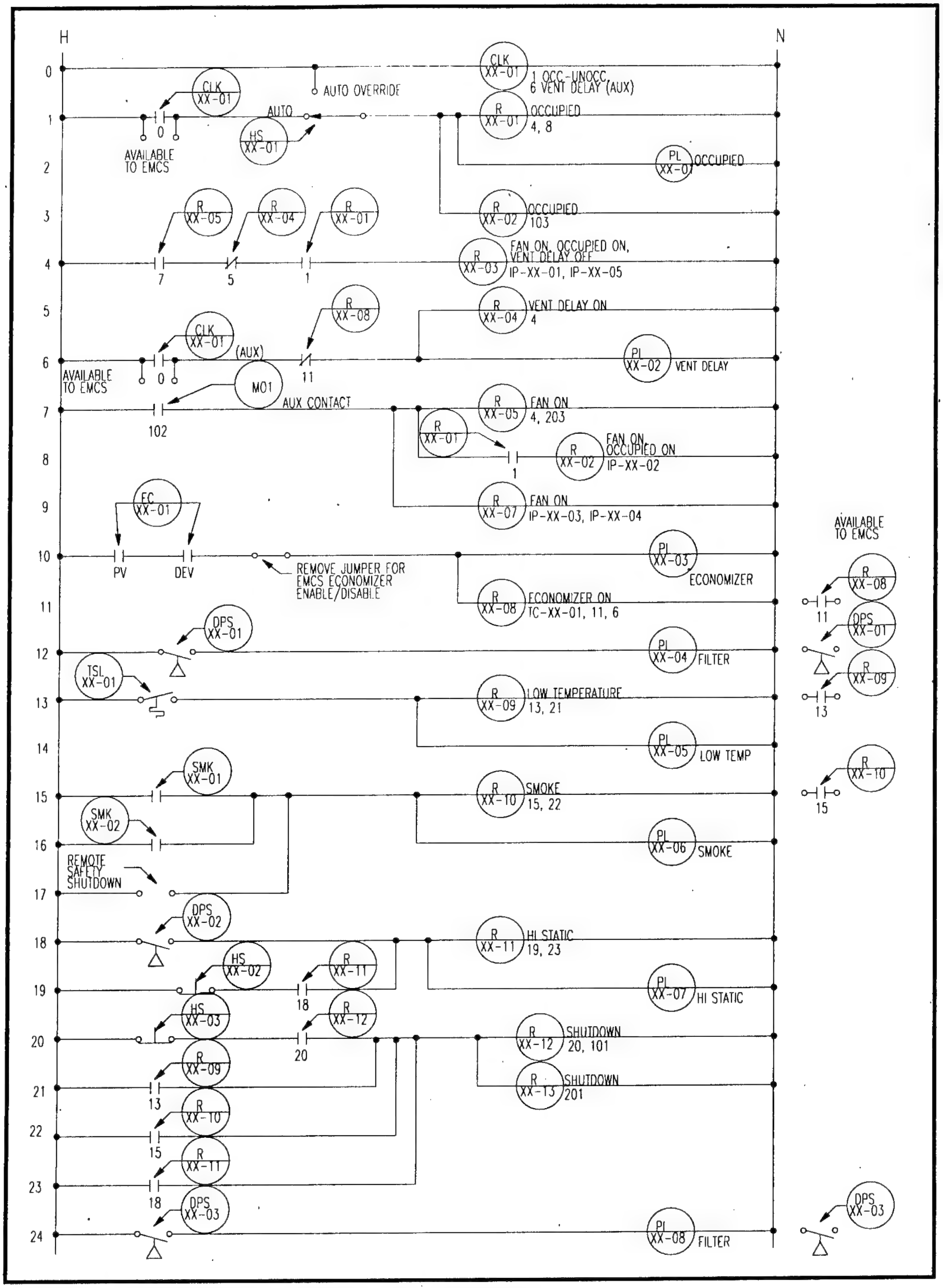


Figure 52. Ladder diagram for return fan VAV control panel.

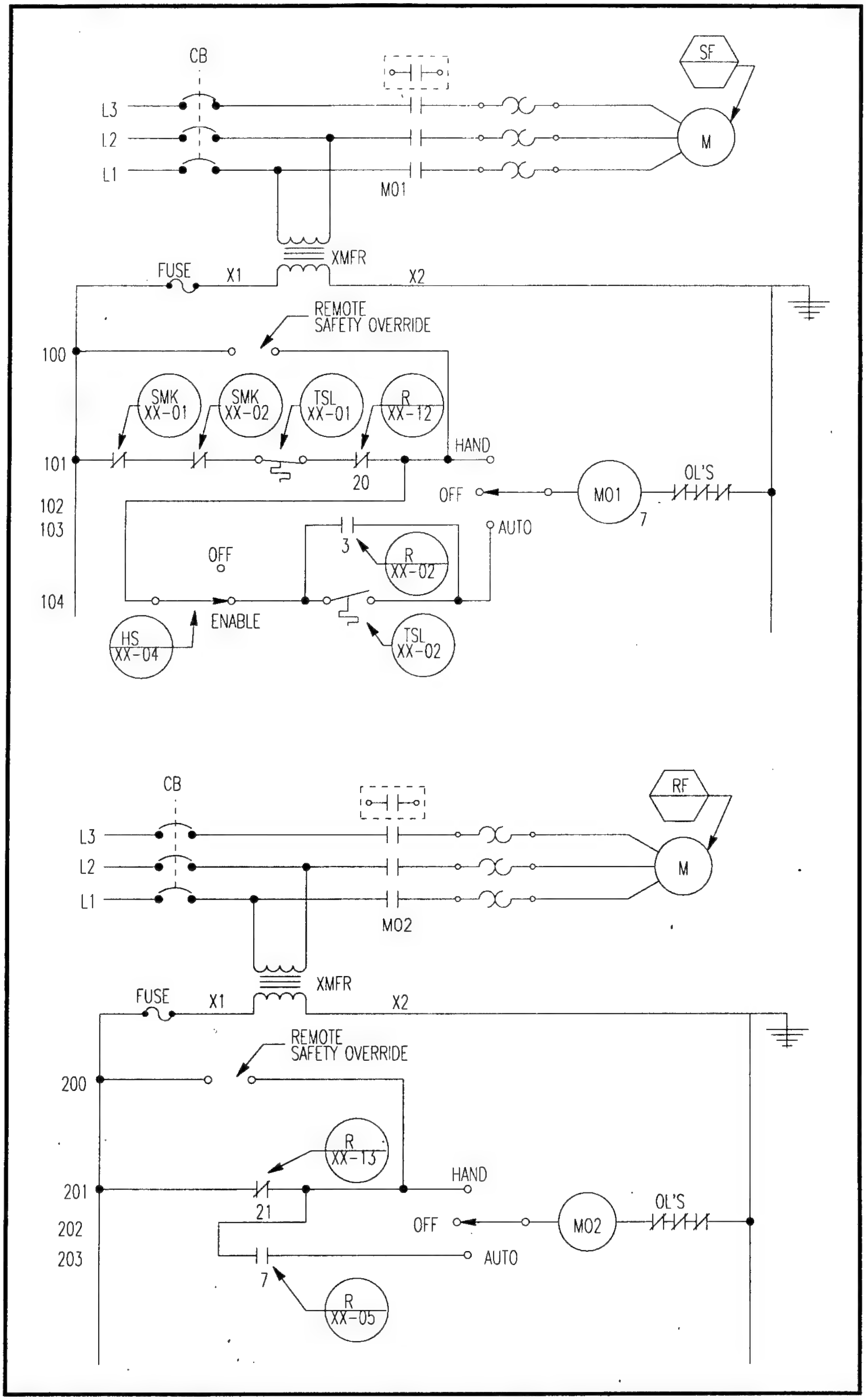


Figure 53. Ladder diagram for return fan VAV motor starter.

Sequence of Operation

1. A pressure sensing element and transmitter DPT-XX-01 located in the supply duct (the location is determined by field conditions) signals duct static pressure to controller PC-XX-01. Whenever the supply fan runs, the auxiliary contacts of the fan starter energize relay R-XX-07. The output of pressure controller PC-XX-01 is sent, through the contacts of relay R-XX-07, to current-to-pneumatic transducer IP-XX-03. The pneumatic output of the transducer modulates the supply fan inlet vane actuator DA-XX-04 to maintain the pressure controller setpoint. When the fan is de-energized, relay R-XX-07 is de-energized, its contacts open, and the inlet vane dampers remain closed.
2. When the setpoint of high limit static pressure switch DPS-XX-02 in the supply fan discharge is exceeded, its contacts close, energizing relay R-XX-11 and lighting high-static pilot light PL-XX-07. One set of the contacts of relay R-XX-11 locks in relay R-XX-11, and another set of contacts energizes relays R-XX-12 and R-XX-13. One set of the contacts of relay R-XX-12 locks in relays R-XX-12 and R-XX-13, and the other set of contacts de-energizes the supply fan. The contacts of relay R-XX-13 de-energize the return fan. To restart the fans, manual switch HS-XX-02 must be momentarily depressed and then manual switch HS-XX-03 must be depressed.

Equipment Schedule

Figure 54 shows the equipment schedule for the return fan VAV system.

Equipment Schedule Information

- DA-XX06 operates the return fan inlet guide vanes and operates over 3 - 15 psig.
- FC-XX01 has a setpoint of _____, over a range of 0 to 20,000 cfm.
- FT-XX01 is in the supply duct and has a range of 0 to 20,000 cfm.
- FT0-XX01 is in the return duct and has a range of 0 to 20,000 cfm.

LOOP FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDTL. PARAMETERS
RETURN FAN VOLUME	DA-XX-06	RETURN FAN INLET VANE ACTUATOR	—	21 - 103 kPa (3-15 PSIG)	—
	FC-XX-01	RETURN FAN VOLUME CONTROLLER	SUPPLY FAN L/s (CFM) MINUS __ L/S (__ CFM)	0 - 9500 L/s (0 - 20,000 CFM)	—
	FT-XX-01	SUPPLY DUCT FLOW TRANSMITTER (FPM)	—	0 - 9500 L/s (0 - 20,000 CFM)	—
	FT-XX-02	RETURN DUCT FLOW TRANSMITTER (FPM)	—	0 - 9500 L/s (0 - 20,000 CFM)	—

Figure 54. Equipment Schedule for return fan VAV system.

Return Fan Controller Configuration Parameters

In this control loop, the single-loop digital controller performs several critical functions:

- It reads the supply duct **fpm** flow and converts it to **cfm.**
- It subtracts the **bias** setting from the supply duct flow and makes this result the control **setpoint.**
- It reads the return duct **fpm** flow and converts it to **cfm.**
- It controls the return fan inlet guide vanes (or variable speed drive) to maintain the return duct **cfm** at **setpoint.**

Figure 55 shows a sample configuration checksheet for a return fan controller and description of the most important configuration parameters:

Remote Setpoint High and Low Range

The signal from the supply duct flow sensor is applied to the CPA port (remote setpoint input) of the controller. The 4-20 mA sensor signal represents feet per minute (fpm), but since we are controlling cfm flow, the controller needs to convert the 4-20 mA fpm signal to cfm. This is done by configuring the controller to the range of sensor.

For example, if the supply duct flow sensor has a range of 0 to 1200 fpm, and the size of the duct where the sensor is located is 10 sq ft, then the controller remote setpoint (RSP) input settings should be configured for:

RSP low = 0 cfm

RSP high = 1200 fpm x 10 sq ft = 12,000 cfm

Note: with some controllers the RSP (or CPA) is also referred to as "analog input 2 in. because it is the second input to the controller (the first input is the PV input).

Max and Min Setpoints

The maximum and minimum setpoints are not the same thing as the setpoint high and low ranges (although it is sometimes difficult to tell the difference between these them due to fuzzy descriptions found in the controller manufacturers manuals). The max and min setpoint simply place limits on the upper and lower range of the setpoint. This is similar to a mechanical stop on a damper or actuator.

RETURN FAN CONTROLLER
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	rEv (direct or reverse)
Setpoint Derived from	SPF	AI2 (panel or AI2)
Low limit of setpoint	SPLL	0 (adjustment lo range)
High limit of setpoint	SPHL	24000 (adjustment hi range)
Calibration for AI2	CAL2	rtbs (Ratio & Bias)
Ratio	rAtE	1.0 (supply flow)
Bias	bIAS	-3800 (subtracted for supply flow)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dis
Digital Input 2	dI2-	dis
Alarm 1 Action	AL1-	hI
Alarm 1 Type	AL1t	abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	24,000
Alarm 1 Hysteresis	Hys1	1000 (deadband)
Alarm 2 Action	AL2-	hI
Alarm 2 Type	AL2t	abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	24,000
Alarm 2 Hysteresis	Hys2	1000 (deadband)
Proportional band	P---	200 %
Integral value	I---	30 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	0.0 (sensor/FT range)
Process Variable (PV) High Range	HI1-	24000 (sensor/FT range)

Figure 55. Return fan controller configuration checksheet.

PV High and Low Range

The signal from the return flow sensor is applied to the PV input of the controller. The 4-20 mA sensor signal represents feet per minute (fpm), but since we are controlling cfm flow, the controller needs to convert the 4-20 mA fpm signal to cfm. This is done by configuring the controller to the range of the sensor. For example, if the return duct flow sensor has a range of 0 to 1200 fpm, and the size of the duct where the sensor is located is 20 sq ft, then the controller PV input settings should be configured for:

PV low = 0 cfm

PV high = 1200 fpm x 20 sq ft = 24,000 cfm

Note: Most controllers will not accept large numbers for the PV high and low range because of the display size limitations. Typically, the number cannot be any larger than 4 digits. As a result, in the example above, you cannot enter a PV high configuration parameter of "24000" cfm because it is five digits. In this case enter "2400" instead. The controller will only display 2400, so when you are reading the display, you will need to remember to add a zero to the number displayed by the controller (you might want to write "x 10" on the control panel next to the controller).

Bias

The controller bias setting is used to make sure that the return airflow brought through the return duct is less than the supply air flow. The bias is added to or subtracted from the control setpoint. Usually we will want to subtract it. For example, if we know that the building has 2000 cfm of exhaust (from the bathrooms), then we would want to bring back (return) 2000 cfm less than the supply fan is delivering. Therefore the bias is:

Bias = building exhaust fans = -2000 cfm (note the negative number)

But since we also want to pressurize the building the bias should be more than 2000. A rule of thumb is to make the bias setting equal to the building exhaust fans flow plus 10 percent of the design air flow. The exhaust fans flow and design airflow can usually be found in the mechanical drawings in the air handler schedule. For example, if the design flow is 18,000 cfm, then the bias should be configure for:

Bias = building exhaust fans + 10% of design flow

= 2000 cfm + (0.10 x 18,000 cfm)

= 2000 cfm + 1,800 cfm

= -3800 cfm (note the negative number)

The bias can be entered directly into the controller. In this example, the bias configuration parameter is minus 3800 cfm (-3800). This value is the difference in cfm flow that the controller will maintain between the supply and return ducts.

Return Fan Control Loop Troubleshooting

Return fan control can be troublesome. Typical problem symptoms include:

- A VAV system with a return fan and relief air ducting at the air handler (which usually accompanies an economizer) should have slightly negative pressure at the mixed air section. A simple pressure test can be performed by opening the access door to the mixed air section. Positive pressure in the mixed air section suggests that the return fan is overdriving the supply fan. Highly negative pressure in the mixed air section suggest that the return fan is not moving enough air.
- Cold air drafts and or dirt/dust being drawn into the building, and or doors hanging open from too much pressure in the building.
- No outside air being drawn in through the air handler OA intake (air might actually be exhausted through the OA intake).
- No air being exhausted out the air handler relief air duct (air might actually be pulled in though the relief/exhaust air duct).

The above problems can be caused by:

- Improper actuation of the inlet guide vanes where the guide vane linkages are loose, improperly set, or disconnected.
- Improper bias configuration parameter set into the controller. Bias settings are described above.
- Airflow measurements (supply and/or return) that are incorrect. Airflow measurement is described in Chapter 6, "Control Hardware Troubleshooting."
- Uncontrolled supply fan that is not maintaining duct static pressure setpoint.

Humidity Control Loop

A humidity control loop is shown in Figure 56.

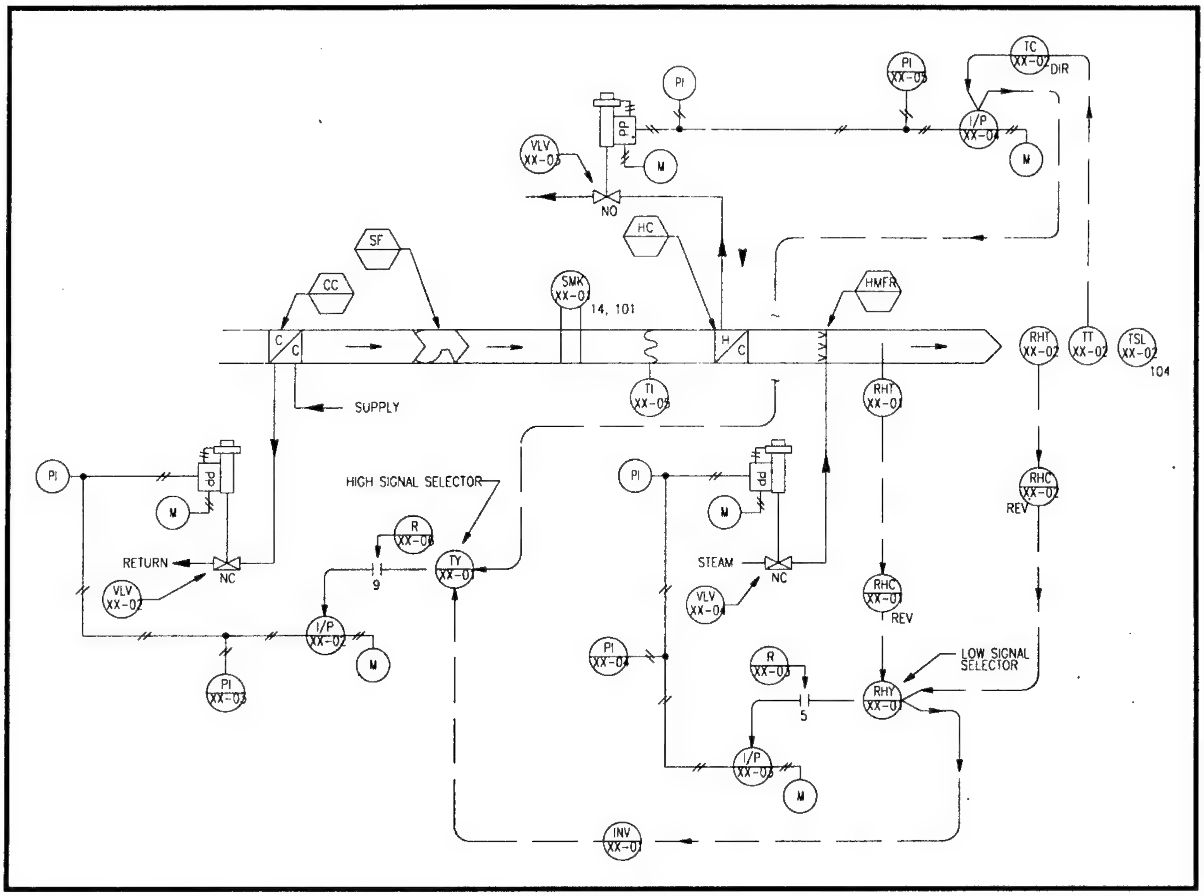


Figure 56. Humidity control loop schematic.

Ladder Diagram Information

Figures 57 and 58, respectively, show the humidity control system valve sequencing, and a ladder diagram for a humidity control.

- R-XX03 on line 5 is in the control circuit to IP-XX03, it is controlled by R-XX05, R-XX04, and R-XX01 on line 5.
- R-XX06 on line 9 is in the control circuit to IP-XX02, it is controlled by R-XX02 NO contact on line 9 and MO1 AUX Contact on line 8.

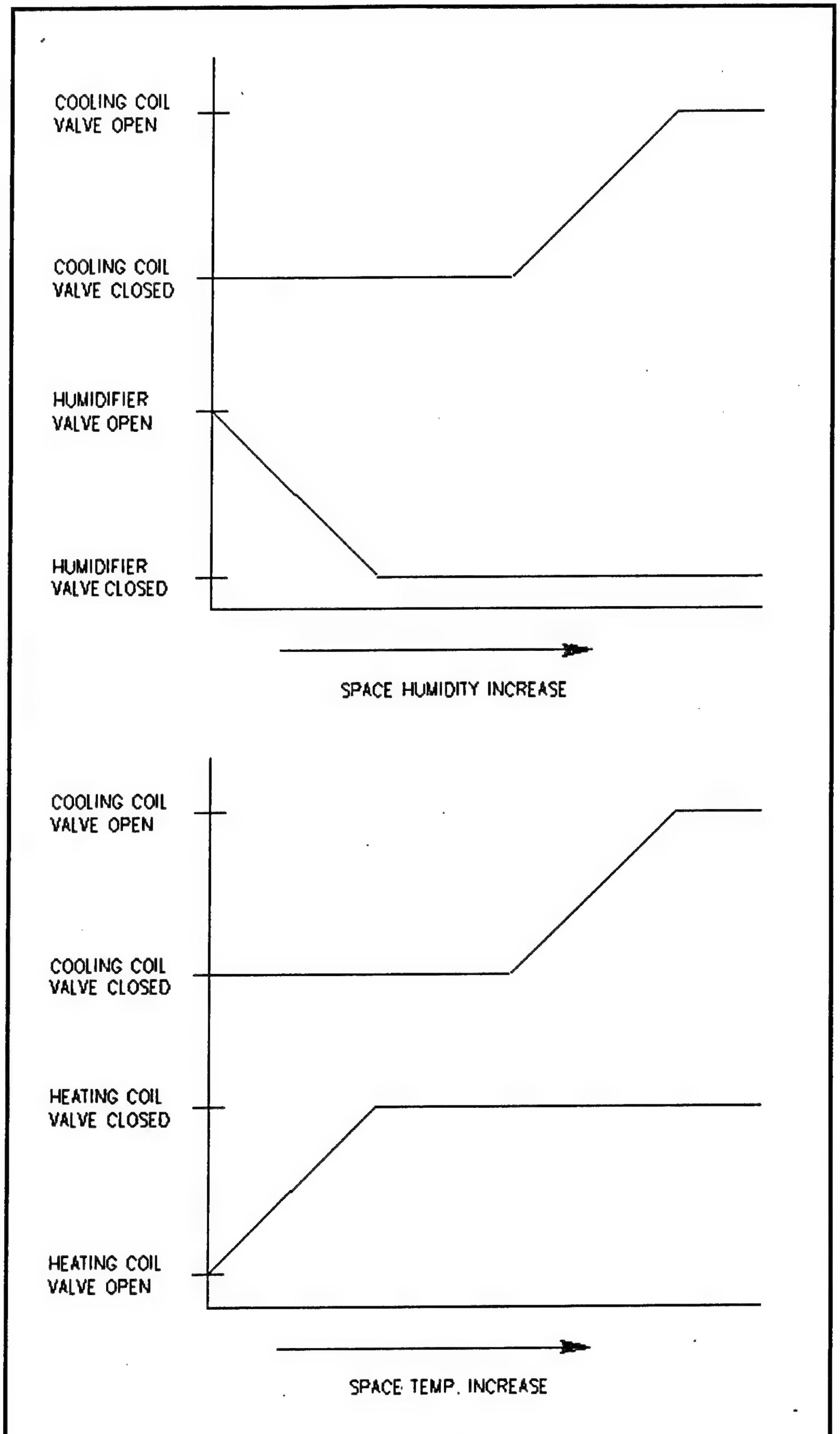


Figure 57. Humidity control system valve sequencing.

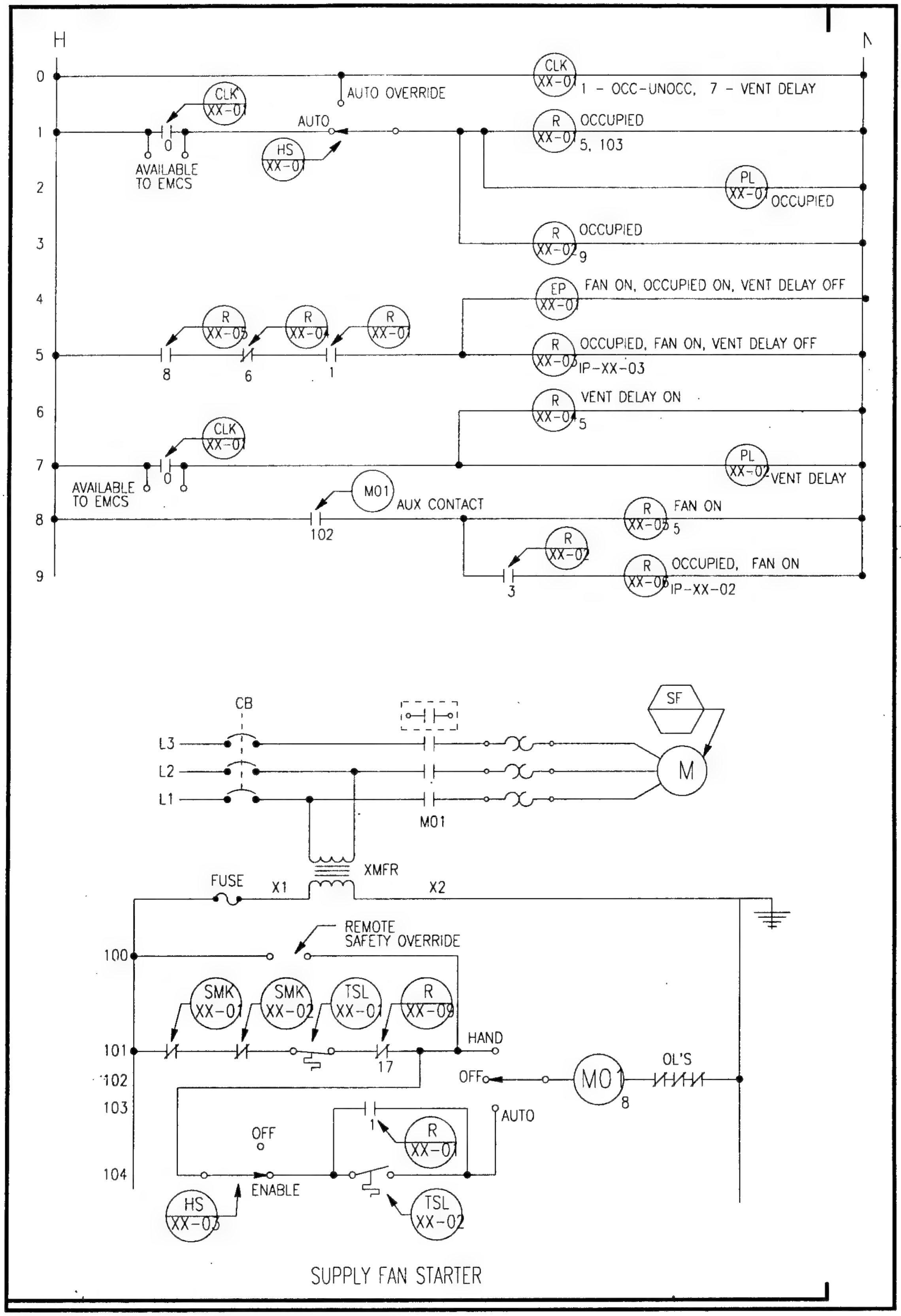


Figure 58. Humidity control ladder diagram.

Sequence of Operation

1. Space temperature transmitter TT-XX-02 signals the space temperature to temperature controller TC-XX-02. The output of TC-XX-02 is received by current-to-pneumatic transducer IP-XX-04 and high signal selector TY-XX-01. The pneumatic output of current-to-pneumatic transducer IP-XX-04 modulates the reheat coil valve VLV-XX-03. High signal selector TY-XX-01 passes the higher of the temperature signal and the humidity signal (next paragraph) during the ventilation delay and occupied modes to current-to-pneumatic transducer IP-XX-02. The pneumatic signal of IP-XX-02 modulates the cooling coil valve VLV-XX-02 to maintain the space temperature or humidity setpoint.
2. Space humidity transmitter RHT-XX-02 signals the space relative humidity to relative humidity controller RHC-XX-02. The output of relative humidity controller RHC-XX-02 is transmitted to low signal selector RHY-XX-01 and inverter INV-XX-01. Low signal selector RHY-XX-01 also receives a signal from unit discharge high limit humidity controller RHC-XX-01 (must be proportional only), which receives unit discharge relative humidity signals from unit discharge relative humidity transmitter RHT-XX-01. The output of RHY-XX-01, during the occupied mode only, is received by current-to-pneumatic transmitter IP-XX-03, and the pneumatic output of IP-XX-03 modulates humidifier steam valve VLV-XX-04. The signal from controller RHC-XX-02 to inverter INV-XX-01 is reversed and sent to high signal selector TY-XX-01. The signal from space temperature controller TC-XX-02 (previous paragraph) and the signal from space relative humidity controller RHC-XX-02, after inversion are compared, and the higher signal, during the ventilation delay and occupied modes, is sent to current-to-pneumatic transducer IP-XX-02. The pneumatic signal of IP-XX-02 modulates the cooling coil valve VLV-XX-02 to maintain the space temperature or humidity setpoint.

Figure 59 shows an equipment schedule for humidity control loops.

LOOP CONTROL FUNCTION	DEVICE NUMBER	DEVICE FUNCTION	SETPOINT	RANGE	ADDITIONAL PARAMETERS
SPACE TEMPERATURE	TT-XX-02	SPACE TEMPERATURE TRANSMITTER	—	10 TO 30 DEG C (50 TO 85 DEG F)	—
	TC-XX-02	SPACE TEMPERATURE CONTROLLER	24 DEG C (75 DEG F)	10 TO 30 DEG C (50 TO 85 DEG F)	—
	VLV-XX-02	COOLING COIL VALVE	—	69 - 103 kPa (10 - 15 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
	VLV-XX-03	REHEAT COIL VALVE	—	21 - 55 kPa (3 - 8 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)
RELATIVE HUMIDITY	RHT-XX-01 RHT-XX-02	RELATIVE HUMIDITY TRANSMITTER	—	0 TO 100 % RH	—
	RHC-XX-01	SUPPLY DUCT REL. HUM. HI-LIMIT CONTROLLER	SETPOINT = 90 % RH PROPORTIONAL BAND = 10 % MANUAL RESET = 50 %	0 TO 100 % RH	—
	RHC-XX-02	SPACE RELATIVE HUMIDITY CONTROLLER	50 % RH	0 TO 100 % RH	—
	VLV-XX-04	HUMIDIFIER VALVE	—	69 - 103 kPa (10 - 15 PSIG)	Kv = _ (Cv = _) CLOSE AGAINST _ kPa (_ PSIG)

Figure 59. Equipment Schedule for humidity control loops.

Humidity Controller Configuration Parameters

Figures 60 and 61, respectively, show configuration checksheets for a space humidity controller and a duct humidity controller. Duct high limit humidity controller configuration parameters are shown in the configuration checksheet. Using the settings as shown, the controller acts more as a switch than a modulating controller. It will move the humidifier valve from full open to full closed as the duct humidity changes from 80 %RH to 84 %RH. Widening the proportional band to 20 %RH will cause the valve to modulate full range over a duct humidity of 80 %RH to 88 %RH. Space Humidity controller configuration parameters are shown in the configuration checksheet.

Humidity Loop Troubleshooting

If the duct humidity controller consistently displays 100 %RH, The duct humidity sensor may either be the wrong type, defective, or too close to the humidity injection element. The sensor should be located at least 10 ft downstream of the humidity injection element. A resistive type humidity sensing element is best to measure duct humidity. It tends to function better at high humidities compared to a capacitive type element.

Proper sequencing of the control valves is critical. The positive positioner spans must be set as shown in the Equipment Schedule.

When the space is calling for cooling and humidification at same time, the duct can saturate if the high limit controller is not functioning properly.

SPACE HUMIDITY CONTROLLER
CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	rEv (direct or reverse)
Setpoint Derived from	SPF	panel(panel or AI2)
Low limit of setpoint	SPLL	40 (adjustment lo range)
High limit of setpoint	SPHL	60 (adjustment hi range)
Setpoint	SP–	50 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dls
Digital Input 2	dI2-	dls
Alarm 1 Action	AL1-	Hi
Alarm 1 Type	AL1t	abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	100
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	Hi
Alarm 2 Type	AL2t	abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	100
Alarm 2 Hysteresis	Hys2	2 (deadband)
Proportional band	P---	10 %
Integral value	I---	120 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	0 (sensor/TT range)
Process Variable (PV) High Range	HI1-	100 (sensor/TT range)
Communications Port type	Port	____
Protocol	PtcL	____
Address	Addr	____
Baud	bAUd	____

Figure 60. Space humidity controller configuration checksheet.

DUCT HUMIDITY CONTROLLER

CONFIGURATION CHECKSHEET

	Upper Display	Lower Display
Control Action	Act	Rev (direct or reverse)
Setpoint Derived from	SPF	panel(panel or AI2)
Low limit of setpoint	SPLL	80 (adjustment lo range)
High limit of setpoint	SPHL	90 (adjustment hi range)
Setpoint	SP–	90 (not shown if AI2)
Action for AO2	Ao-2	rstp (2nd output)
Manual reset value	rStP	12 mA
Minimum controller output	AoLL	4 mA
Maximum controller output	AoHL	20 mA
Digital Input 1	dI1-	dls
Digital Input 2	dI2-	dls
Alarm 1 Action	AL1-	Hi
Alarm 1 Type	AL1t	abs
Alarm 1 Offset or Setpoint	oFF1 or AL1u	100
Alarm 1 Hysteresis	Hys1	2 (deadband)
Alarm 2 Action	AL2-	Hi
Alarm 2 Type	AL2t	abs
Alarm 2 Offset or Setpoint	oFF2 or AL1u	100
Alarm 2 Hysteresis	Hys2	2 (deadband)
Proportional band	P---	10 %
Integral value	I---	0 seconds
Derivative	d---	0 seconds
Process Variable (PV) Low Range	Lo1-	0 (sensor/TT range)
Process Variable (PV) High Range	HI1-	100 (sensor/TT range)
Communications Port type	Port	____
Protocol	PtcL	____
Address	Addr	____
Baud	bAUd	____

Figure 61. Duct humidity controller configuration checksheet.

6 Control Hardware Troubleshooting – Single-Loop Controller

Configuration

Improper setting of the controller configuration parameters is one of the most common problems you will encounter. If you suspect this is the case, check the configuration settings by comparing them to those shown on the contractor supplied configuration checksheet, or by comparing them to the example configuration checksheets shown in Chapter 5, *Control Loops Troubleshooting*), or by comparing them to another similar controller. Configuration details, specific to the different control loop applications (cooling coil, economizer, outside air temperature controller, etc.), are described in Chapter 5.

General Troubleshooting

Table 1 lists controller problem diagnosis and troubleshooting steps. Table 2 describes a quick 4-step method to determine if a controller is operating properly.

Controller Calibration and Adjustment

The electronics inside an SLDC are factory calibrated should never require field calibration. If they do require calibration, refer to the controller operators manual. The only adjustments that may be required for the controller is setting of the controller configuration parameters. These are set initially by the contractor when the controller is installed and are recorded on the controller configuration checksheet. In most cases these parameters should not require any further adjustment for the life of the controller.

Controller configuration parameters that may require field adjustment include; PID tuning constants, PV contact setpoint, deviation contact setpoint; and for the reset controller (also called outside air temperature controller), reset schedule parameters that include the proportional band, setpoint, and the maximum output signal. Chapter 5 describes reset controller adjustments.

Table 1. Quick 4-step controller troubleshooting procedure

Quick 4-Step Controller Troubleshooting Procedure

This step-by-step procedure applies to controllers with a modulating output (to position a valve, damper, or fan capacity). It also applies to set point reset controller (outside air temperature controller). It does not directly apply to an economizer controller, although a similar thought process would apply:

1. Temperature. Note the process variable temperature (the "upper" display on a single-loop digital controller). The same thing applies in the case of a pressure, humidity or flow controller.

2. Setpoint. Note the controller set point (the "lower" display on a single-loop digital controller).

3. Action. Note the control action (direct or reverse) by checking the "control action" configuration parameter that has been entered into the controller. You may need to refer to the controller operators manual if you are not familiar with operating the controller. Make sure that the control action setting (direct or reverse) is correct for the application.

4. Output. Check the controller output signal. There are several ways of doing this and it depends on the which manufacturers controller you are using. With most controllers pushing a button on the front of the controller changes its display to show output in either mA (4-20mA) or percent (0-100%). With the Basys SD-1000, push the self-tune button two times so that the self-tune light is lit (but not blinking). Using the information from steps 1, 2, and 3;

If the temperature is below setpoint, and the action is;

- Direct, the controller is "OK" if the output is small (close to 4mA or 0%)
- Reverse, the controller is "OK" if the output is large (close to 20mA or 100%)

If the temperature is above setpoint, and the action is;

- Direct, the controller is "OK" if the output is large (close to 20mA or 100%)
- Reverse, the controller is "OK" if the output is small (close to 4mA or 0%)

Note: Checking the controller output by reading the pressure gage of the signal being sent to the controlled device can be misleading because the pressure signal to the device might actually be from another device such as a minimum position switch or an open control relay contact.

☞ *If the controller checks OK – do not mess with it. Something else is wrong!* ☜

(If you still suspect that the controller is the problem, check the configuration settings by comparing them those shown on the contractor supplied configuration checksheet or by comparing them to the example configuration checksheets shown in the Chapter 5, "Control Loop Troubleshooting .")

Table 2. Controller troubleshooting

Problem	Troubleshooting/Possible Cause
No display (controller appears dead)	Circuit breaker to panel is off. Fuse in lower left corner of panel blown. Fuse inside controller is blown. Controller not seated properly in housing. Power wiring to controller not wired properly. Internal jumper set incorrectly (i.e., it may be jumpered for 220 VAC instead of 115 VAC). If none of the above, repair or replace controller.
Controller display is unusual (does not display the process variable or setpoint)	Push the "DISPLAY" or "SCROLL" button (you may have to push it several times).

Problem	Troubleshooting/Possible Cause
Improper display of process variable (upper display)	If it displays a code, word, or lettering, this usually means that the sensor input is disconnected, wired incorrectly (reverse polarity), or the sensor is faulty. Refer to the controller operators' manual for exact interpretation of displayed codes.
	Display of "LLLL" means that the PV (sensor input) has dropped below 4mA. This is normal if the PV (i.e., temperature) has dropped below the range of the transmitter such as in a HW system when the boiler is turned off. Otherwise the sensor might be defective, wired incorrectly, or is disconnected.
	Display of "HHHH" means that the PV (sensor input) has risen above 20mA. This usually means the sensor is faulty.
	The sensor may be out of its normal sensing range (i.e., if a hot water sensor range is 100 to 250 °F and the water temperature it is reading is 90 °F, the controller will display a code to indicate there is a problem. In this case the controller will return to normal operation when the water temperature increases.
	The controller may be configured wrong. Check the contractor supplied "controller configuration checksheet" to ensure that the controller process variable input parameters are consistent with those on the checksheet.
	The input transmitter may be faulty (see "Transmitter Problem Diagnosis and Troubleshooting")
	If all controllers in the panel have an improper process variable display, the 24 VDC power supply inside the control panel may be faulty (this power supply is used to power all sensors).
Displays do not respond to front panel keys	Press the hidden reset button on the face of the controller (above the auto-tune button).
	Determine if there is a fault (is there a fault light and is it lit?). If there is a fault, acknowledge the fault by pushing the appropriate button (usually this is the "ACK" button).

Controller Repair/Replacement

In general it probably is best to just replace a malfunctioning controller. The time and effort required to repair a controller may not be justified although some manufacturers will diagnose the controllers for no charge. By design and specification, SLDCs are fully interchangeable, not only between applications but also between manufacturers. This is due to their 1/4 DIN physical size, 4 to 20 mA input/output requirements, and the functional capability of the controllers. Therefore, replacement controllers may be obtained from the most convenient and cost-effective source. However, not every SLDC on the market will meet the application requirements. Most will meet basic application requirements; but to meet interchangeability requirements, the SLDC must meet all the requirements in CEGS-15950. Use caution in selecting standard controllers. It is not always evident from the vendors specification sheet that the unit will meet

CEGS-15950 requirements. Controllers known to meet CEGS-15950 requirements are:

- Honeywell UDC 3000
- TCS Basys SD-1000
- Yokogawa UT-30
- Yokogawa UT-40.
- Powers 512
- Powers 535
- Taylor Micro Scan 500

The TCX for HVAC Controls may be consulted for a current list of controllers known to meet CEGS-15950 requirements or to check requirements of a prospective replacement controller. Controller features to look for that may not be evident from a vendor's specification sheet include:

- The PV and DEV contacts must be separate such that they have separate external connections for wiring purposes.
- The control (or primary) output from the controller should not be used as a relay contact. There should be two separate relay contacts for contact closure outputs in addition to a 4 to 20 mA control output.
- Do not use a controller that continuously self-tunes. The operator should be able turn the self-tune feature on, and then disable it when self-tuning is complete.
- The controller depth should not exceed the depth of the control panel.

A replacement controller must be configured for the application it is to be used in. The same configuration parameters from the defective controller should be used in the replacement controller. These parameters can be found on the controller configuration checksheet provided by the contractor as a contract submittal when the control system was originally installed. Chapter 5 of this manual also describes controller configuration and includes sample configuration checksheets. The operators" manual accompanying the replacement controller will be needed to configure the controller.

Controller Wiring Diagrams and Control Panel Terminal Blocks

Figures 62 and 63 show typical controller input add output wiring connections. Figure 62 is for a controller used in a modulating control application. Figure 63 is for a controller used in an economizer control application Figure 64 shows the arrangement of the terminal blocks across the back of the inside of the control panel.

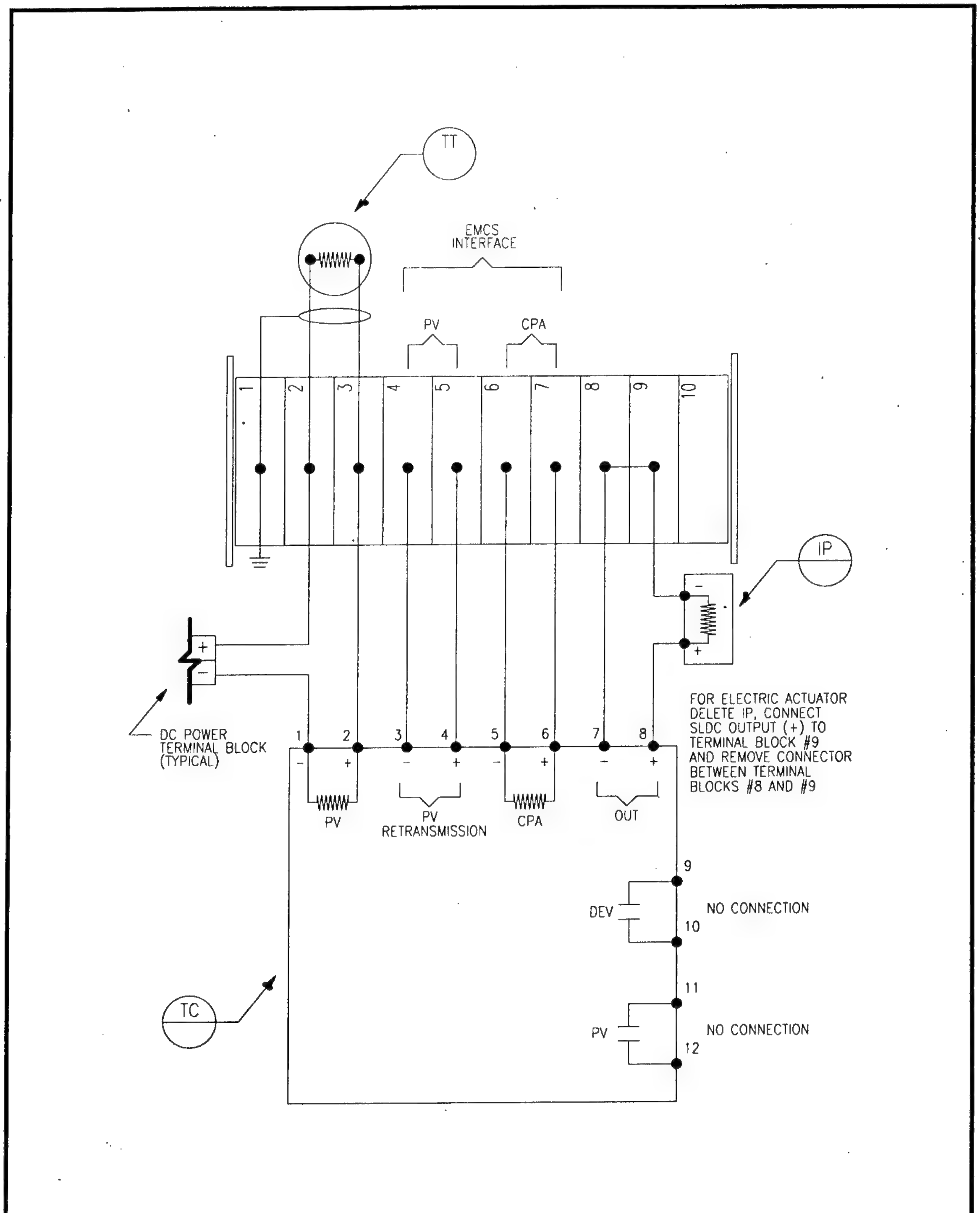


Figure 62. SLDC wiring details (typical).

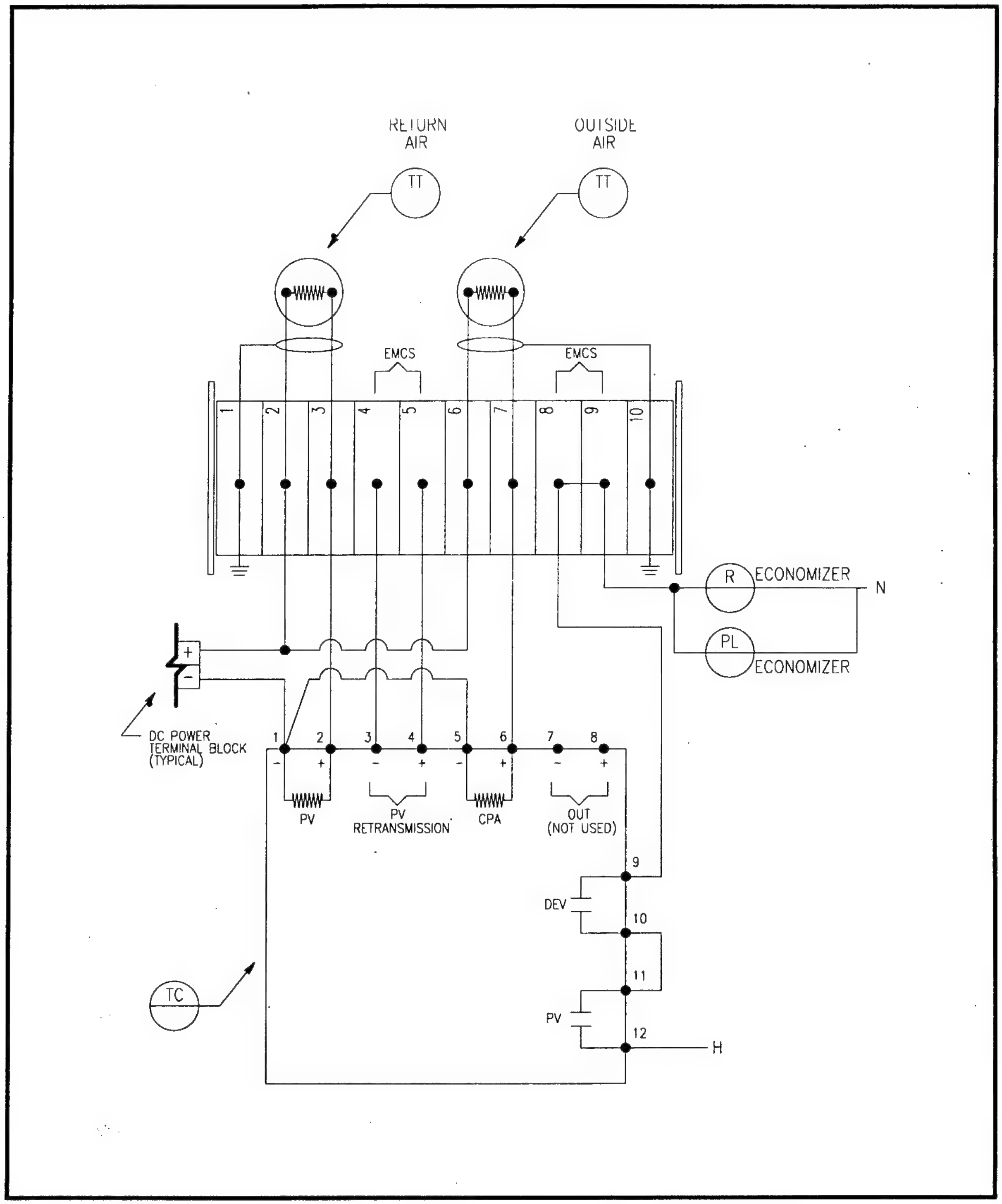


Figure 63. SLDC economizer wiring details.

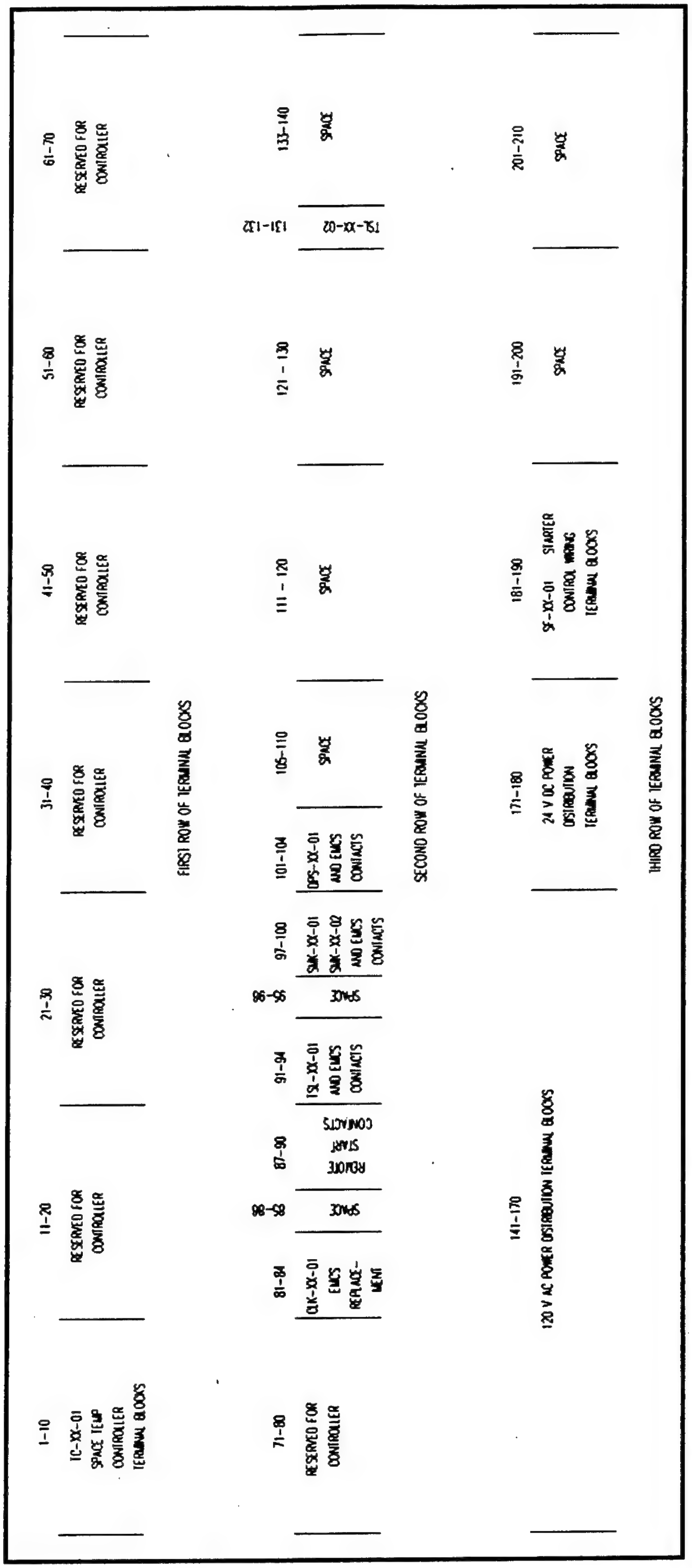


Figure 64. Terminal block layout – inside control panel.

There are three rows of terminal blocks, with each row subdivided into sets of 10 terminal blocks. The terminal block layout shows the specific function of each set of terminal blocks and is similar for each of the standard control systems; but it varies somewhat depending on the individual application requirements. In the first row of terminal blocks, terminals 1 through 10 are dedicated to the heating and ventilating system space temperature controller. Blocks 11 through 70 are not used in this application. In the second row of terminal blocks, terminals 81 through 84 are reserved for interface with EMCS to perform the time clock function (as was described in the ladder diagram section). Also, in the second row are the other EMCS interfaces and safety/interlock connections (including the freezestat, smoke detectors, and filter differential pressure switch). The third row of terminal blocks shows terminals dedicated to connections for 120V AC and 24V DC power distribution and the supply fan motor starter wiring terminal blocks. Detailed wiring connections to each terminal block are shown in the standard wiring diagrams.

Electronics

Component level troubleshooting might be needed in some cases to isolate a defective device. The use of Ohms Law is useful when making voltage measurements during component troubleshooting.

Ohms law is defined as:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

Or:

$$I = \frac{V}{R}$$

Where:

I = current, amps
V = voltage, volts
R = resistance, ohms.

Variations of Ohms Law, based on algebraic manipulation:

$$R = \frac{V}{I}$$

And:

$$V = I \times R$$

A useful aid in remembering Ohms Law and its variations is the Ohms Law circle shown in Figure 65. To use the circle, place your thumb over the value you would like to determine (V, I, or R). The equation for the value you have your thumb on will appear. For example, by placing your thumb on "I," the equation "V/R" appears. So you would divide V by R. When you place your thumb on the "V," the equation "IR" appears. So you would multiply I times R.

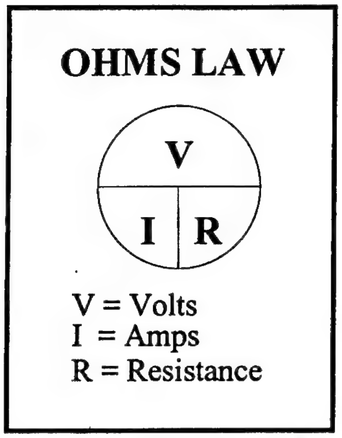


Figure 65. Ohms law circle.

An important note on Ohms Law and control circuits: The control circuits described in this manual operate using milliamp signals, whereas when you use the Ohms Law equation, I = V/R, the result of the calculation is in amps, not milliamps. To adjust for this, when you calculate I=V/R you need to move the decimal place three places to the right. For example:

$$I = \frac{V}{R} = \frac{10\,\mathrm{VDC}}{500\,\mathrm{Ohms}} = 0.020\,\mathrm{amps} = 20\,\mathrm{milliamps}$$

Applied Ohms Law

Figure 66 shows how an SLDC is usually wired. Current (mA) signals can be measured by lifting a wire and putting an ammeter in series with the wiring, but this requires more time and effort than measuring a voltage signal. Voltage measurements can be made without lifting wires. Ohms Law can be used to diagnose the input to or the output from the SLDC by making a voltage measurement. For example if you need to determine the current (mA) value, the measured voltage can be converted to milliamps using Ohms Law. These conversions have been calculated for you in the Tables in Appendix F. Use of the Appendix F Tables are described in the following examples. Appendix E tables can also be used to help in converting milliamp signals to standard temperature transmitter sensor ranges.

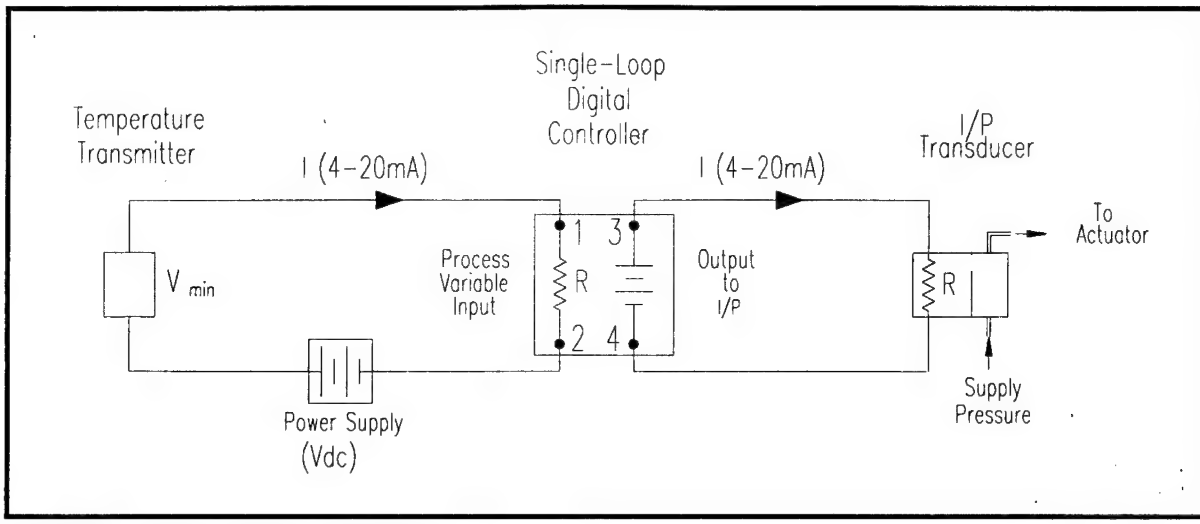


Figure 66. Typical control loop wiring.

Example 1

You suspect that there is a problem with your Basys SD-1000 brand controller because the upper display on the SLDC is displaying "LLLL," which according to the operators manual means that the input has dropped below 4 mA. You had just replaced the sensor, so you are confident that it is not defective, but you want to confirm that it is putting out more than 4 mA.

1. Step 1 - You measure the voltage at the SLDC input terminals ("1" and "2" in this example) and find that it is 0.0 volts.
2. Step 2 - Either your transmitter is defective or it is wired incorrectly.

Example 2

You suspect that there is a problem with your Basys SD-1000 brand temperature controller because the upper display on the SLDC is displaying 102 °F, but the gage in the duct says the temperature is only 90 °F.

1. Step 1 - You measure the voltage at the SLDC input terminals ("1" and "2" in this example) and find that it is 1.72 volts.
2. Step 2 - Determine the sensor range by visually inspecting the temperature transmitter or by reading the Posted Instructions. You find that the sensor range is –30 to 130 °F.
3. Step 3 - Because we have a Basys SD-1000 controller, refer to Table F-3 in the Appendix. In the far left column find 1.72 volts that you measured. In the third column (for a sensor range of –30 to 130 °F), it becomes clear that the temperature is 102 °F.
4. Step 4 - Your sensor and controller are OK. The duct gage is defective or is not sensing the same temperature as the sensor.

Example 3

You are not getting any cooling and you suspect that Basys SD-1000 brand controller is not modulating the chilled water control valve.

1. Step 1 - Place the controller in manual control mode.
2. Step 2 - Adjust the controller output up and down and at the same time measure the voltage at the output terminals ("3" and "4" in this example).
3. Step 3 - If the voltage does not change (remains at 12V DC, for example), the signal is not getting to the I/P transducer and there is an "open" in the output wiring. Check to see if there is an open relay contact in the output loop or if the I/P transducer is not wired up.

Example 4

You are not getting any cooling and you suspect that Basys SD-1000 brand controller is not modulating the chilled water control valve.

1. Step 1 - Place the controller in manual control mode.
2. Step 2 - Adjust the controller output up and down and at the same time measure the voltage at the output terminals ("3" and "4" in this example).
3. Step 3 - At minimum controller output, the voltage is 4V DC and at maximum it is 12V DC.
4. Step 4 - You check the spec sheet for the input resistance of the I/P transducer and find that it is 1000 ohms. Using Ohms Law:
   a. At minimum controller output: I = E/R = 4V DC / 1000 ohms = 4 mA
   b. At maximum controller output: I = E/R = 12V DC / 1000 ohms = 12 mA
5. Step 5 - The output circuit of the controller has too much resistance in it and the controller cannot push 20 mA through it. You check the controller specs and confirm that the controller is rated for only 600 ohm output. You need to replace the I/P transducer with one that is rated at 600 ohms or less, or add a loop driver to the controller output, or replace the controller with one that has a higher output rating.

Control Relay

Figure 67 shows a functional illustration of a the double-pole, double-throw (DPDT) relay. DPDT relays are common in the standard control systems and are used to implement ladder diagram control logic. The relay in Figure 67 is shown in its normal (de-energized) state. Separate input signals can be applied to each of the two poles. There are also two outputs, one for each input.

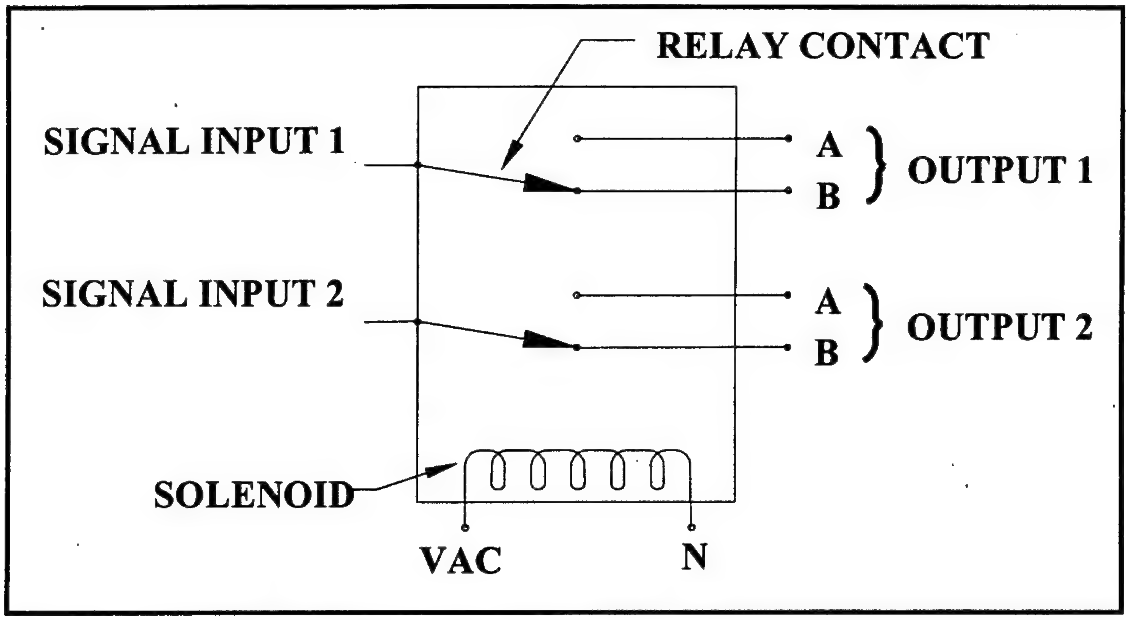


Figure 67. Double pole, double throw relay.

Each output has two throws (output contacts), shown as A and B. When the solenoid is energized (115V AC power applied) the relay contacts switch to route the input signals to the A output contacts. With no power applied to the solenoid, the relay is de-energized, the relay contacts are spring returned to their normal positions, and the input signals are routed to the B output contacts.

Time delay relays are used in some applications. These are functionally similar to the DPDT relay described above except that they delay for a fixed time period after being energized or de-energized before the relay contacts change state. The fixed time period delay is adjustable.

Positive Positioner

A positive positioner is a type of pneumatic relay mounted directly on a pneumatically actuated valve or damper (Figure 68). It accepts a pressure control signal input and provides a pressure signal output to the actuator to position the valve or damper. The positive positioner precisely positions the valve or damper according to the pneumatic control signal and eliminates valve/damper hysteresis (due to friction), regardless of the load (pressure) variations affecting the valve stem or damper shaft. Positive positioners are only used in modulating control applications. They are not necessary in two-position control applications.

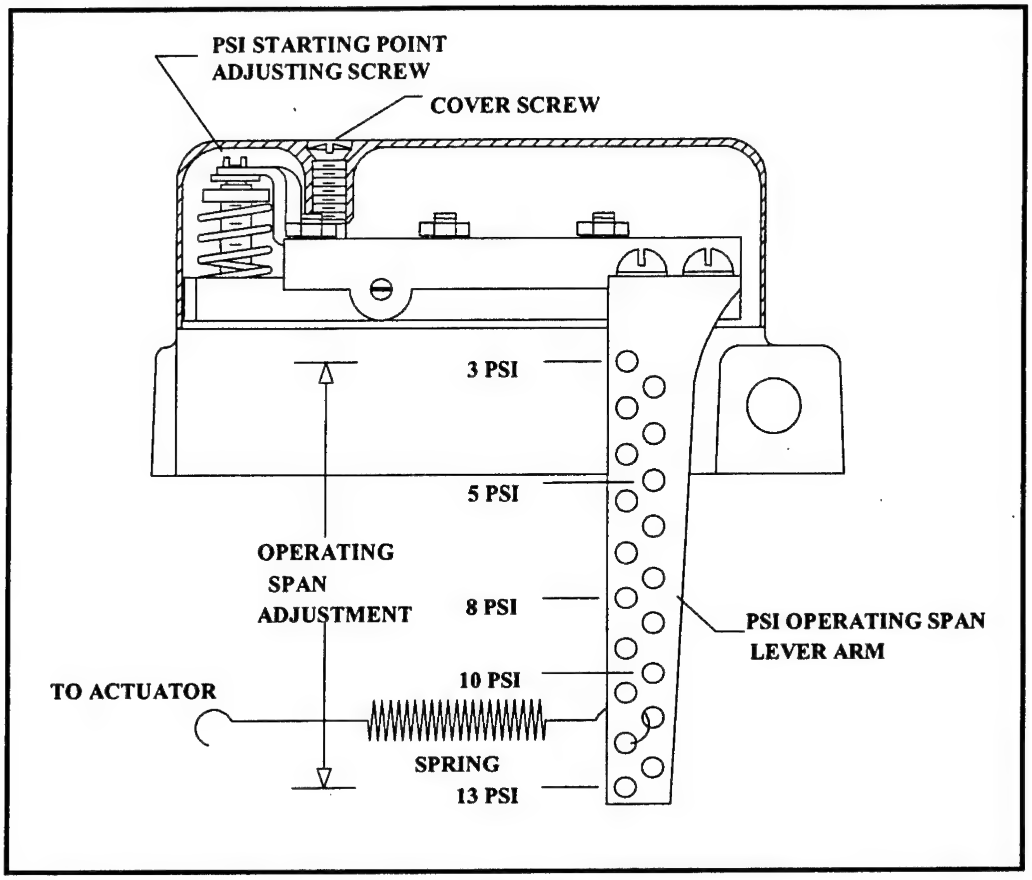


Figure 68. Positive positioner "start point" and "span" adjustments.

Figure 69 shows a positive positioner applied to a damper. The positive positioner moves the actuator in proportion to the control air pressure signal. The spring provides feedback to the positioner on the actual position of the damper shaft. If the connected shaft is not at the required position, or if air pressure in the duct tries to move the shaft from the required position, the positioner exhausts or supplies main air to the actuator in response to the feedback spring to correct the condition. The result is more rapid and precise control under varying load conditions.

The pressure range over which an actuator moves full stroke is dictated by its spring range. Typical actuator spring ranges are 3 to 8 psi and 8 to 13 psi. One benefit of a positive positioner that it can accept the 3 to 15 psi control signal from an IP transducer and cause the actuator to move full stroke over this 3 to 15 psi signal range regardless of the spring range of the actuator. To illustrate, assume a given actuator has a spring range of 8 to 13 psi. The control signal from the IP transducer ranges between 3 and 15 psi. The positioner, mounted on the actuator, can be adjusted to move the actuator full stroke over a range of 3 to 15 psi instead of the 8 to 13 psig spring range of the actuator. Adjusted differently, the positive positioner can provide full stroke actuation over a range of 4 to 10 psi, or 8 to 15 psi, or 3 to 15 psi, etc.

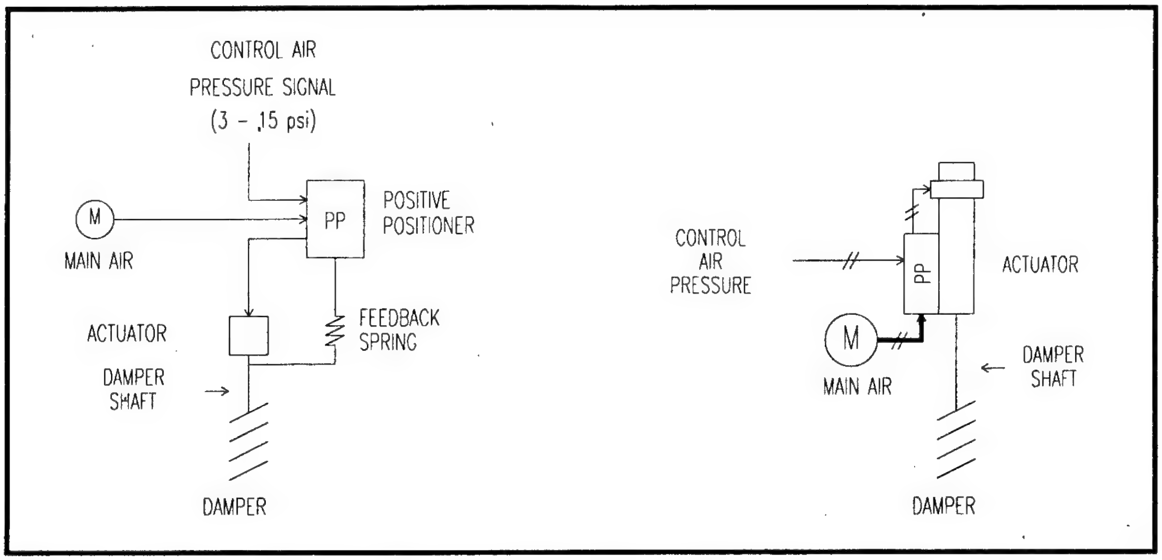


Figure 69. Positive positioner applied to a damper (left) and its standard drawing symbol (right).

The starting point and operating range adjustments of positive positioners are useful to sequence multiple actuators. For example, in a particular application the 3 to 15 psi control signal may be used to modulate both heating and cooling coil valves. The spring range of both valve actuators may be 8 to 13 psi. The positive positioner on each actuator can be adjusted so that the heating coil actuator moves full stroke in response to the 3 to 8 psi portion of the control signal and the cooling coil actuator moves full stroke in response to the 10 to 15 psi portion of the control signal. This avoids simultaneous heating and cooling.

Temperature Sensors / Transmitters

In the standard HVAC control we measure the temperature of both water and air. There are a variety of commercially available temperature sensors. Thermistors and thermocouples are two examples. The platinum resistance temperature detector (RTD) has been selected as the Corps standard sensor for simplicity, nonproprietary replacement, ease of maintenance, accuracy, reliability, and compatibility with EMCS. The RTD sensor is paired up with a temperature transmitter. The sensor measures the process variable temperature and the transmitter generates a linear 4 to 20 milliamp (mA) output representative of the sensed temperature. For example, a space temperature transmitter generates an output signal of 4 mA when the space temperature is 50 °F and 20 mA when the temperature is 85 °F, with a linear relationship. The 4 to 20 mA signal is linear for temperatures between 50 and 85 °F.

The resistance of an RTD increases as the temperature sensed by the RTD increases. This is referred to as a positive temperature coefficient (PTC). There is

nearly an exact linear relationship between the sensed temperature and the resulting RTD resistance. Over an extremely wide range of temperatures the resistance versus temperature relationship is a slightly curved line. In most HVAC applications only a small temperature range is usually measured. Within this range the RTD is very nearly linear. Appendix D-1 contains Tables for converting RTD resistance to temperature.

Manufacturers generally provide specifications for their sensors that define a reference resistance at a reference temperature. The reference temperature of most RTDs is 32 °F. For some RTDs the reference resistance may be 100 ohms at 32 °F. Another typical reference resistance is 1000 ohms at 32 °F. Standard RTDs have a temperature coefficient of 0.00385 ohms per ohm degree centigrade. Note that the temperature coefficient is usually provided in metric units. Given the temperature coefficient of an RTD, you can convert ohms to temperature by:

1. Multiply the reference resistance by the temperature coefficient.
2. Measure the ohms of the RTD
3. Subtract the reference resistance from the measured ohms.
4. Divide the result from step 3 by the result from step 1.
5. Add the result of step 4 to the reference temperature.
6. The result in step 5 is the temperature. You may need to convert from °C to °F.

Continuous averaging RTDs have a long bendable copper sheath. To ensure adequate coverage, the length of the averaging sensor element generally should one linear foot per square foot of cross sectional area of the duct in which it is installed.

Corps standard transmitters are loop-powered. A loop-powered device does not have an external power source connected to it as a separate input. Loop-powered devices have only two wiring connections. One connection provides the 4-20 mA signal output to the device that the transmitter is sending its signal to. The other wiring connection is to the positive terminal of the DC power supply located inside the standard control panel. This wiring is further described in the "Electronics" section of this manual.

RTD transmitters should be selected to match the resistance range of the RTD. Transmitters should also have offset and span adjustments. The following transmitter ranges are typical in Corps HVAC control applications:

1. Conditioned Space: 50 to 85 °F
2. Duct Temperature: 40 to 140 °F except for return air temperature for economizer cycle operation, which is -30 to 130 °F
3. High Temperature Hot Water: 200 to 500 °F

4. Chilled Water: 30 to 100 °F
5. Dual Temperature Water: 30 to 240 °F
6. Heating Hot Water: 40 to 450 °F
7. Condenser Water: 30 to 130 °F
8. Outside Air: -30 to 130 °F

The transmitter range, for a given application, is usually shown the Equipment Schedule drawing.

Figure 70 shows typical control schematic symbols for water temperature and duct air temperature sensors. In each case the temperature sensor is a platinum RTD and is connected to an integrally mounted temperature transmitter (TT) that provides a 4-20 mA output signal. In the duct application, the sensor is an averaging type element. Averaging elements should be used in applications where there is potential for stratification of the air stream as is the case on the downstream side of a coil and in mixed air temperature-sensing applications. Outside and return air temperatures usually can be measured adequately with a point-type sensor.

Figure 71 shows the input/output relationship of a typical temperature transmitter (heating hot water in this example). At the 100 °F lower end of the transmitter range the transmitter outputs a 4 mA signal. At the 250 °F upper end of the transmitter range, the transmitter outputs a 20 mA signal. Between these two extremes the relationship between the sensed temperature and the transmitter output is linear.

If outside air temperature is being measured, a sunshield with adequate ventilation is required so that the RTD sensing element will respond to the actual ambient temperature and not be adversely affected by direct solar radiation.

Airflow Measurement Station (Flow Sensor)

An air flow measuring station is used to measure duct air flow rate in units of feet per minute (fpm) or liters per second (L/s). The device might also be referred to as an air flow measurement array (AFMA). There are two basic types available: pitot tube and electronic. An electronic AFMA (also called a hot wire anemometer) contains heated thermocouples (or other similar) velocity sensing elements. The flow transmitter portion of the AFMA provides a 4-20 mA output signal proportional to the air flow rate.

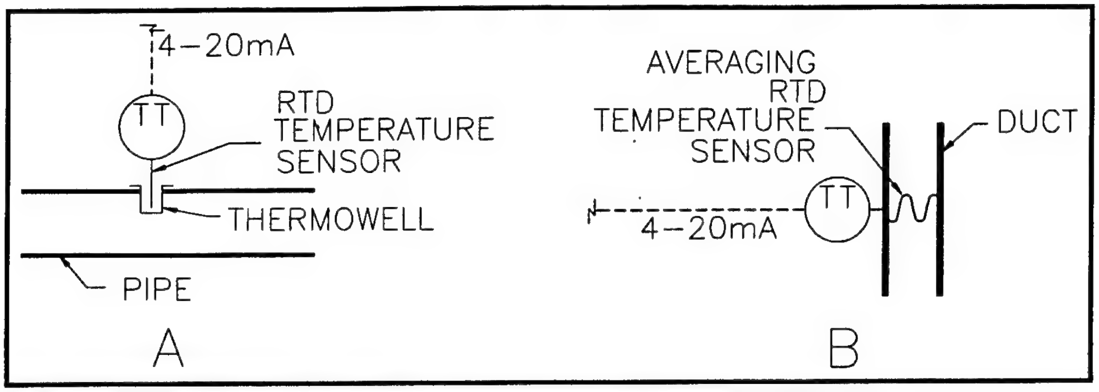


Figure 70. Input/output relationship of a typical temperature transmitter.

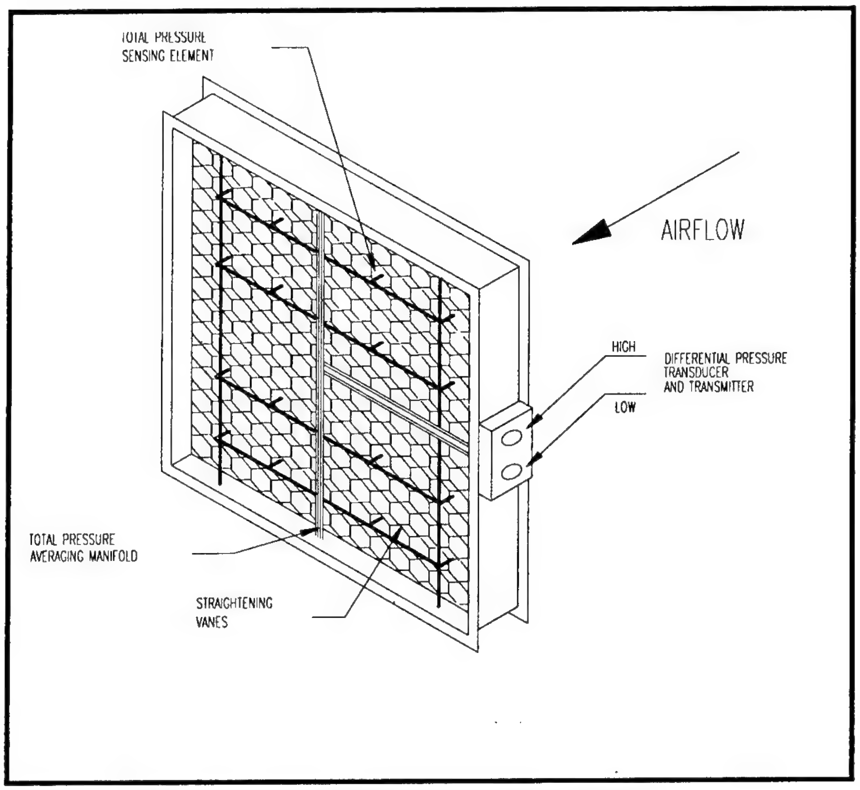


Figure 71. Pitot tube airflow measurement array (AFMA).

Both the pitot tube and electronic types consist of an array of velocity-sensing elements and straightening vanes inside a flanged sheet metal casing. The velocity-sensing elements are to be distributed across the duct cross-section in the quantity and pattern specified by the published installation instructions of the station manufacturer. In some cases, the flow sensing element and straightening vanes might be two separate components.

Because of the inaccuracy inherent in measuring very low velocity pressures, the pitot tube-type stations are not used if the flow measurement is below 700 ft per minute.

A pitot tube-type AFMA (Figure 71) consists of a velocity-sensing element array, which is a series of pitot tubes. The pitot tubes are directed into the air flow and sense total pressure at each of the multiple total-pressure-sensing elements. The total pressures are averaged at the averaging manifold. The differential pressure transducer of the unit measures the velocity pressure by subtracting the total pressure from the static pressure. (Note that the static pressure taps are not visible in the illustration.) The sensed average total pressure (P_{total}) is subtracted from the sensed static pressure (P_{static}) by means of a differential pressure sensing transducer (DPT) to obtain the velocity pressure ($P_{velocity}$):

$$P_{velocity} = P_{total} - P_{static}$$

The transmitter uses linearizing circuitry to take the square root of the transduced velocity pressure resulting in a 4-20 mA output signal that is proportional to the air flow rate over the required air velocity range of the AFMA:

$$\text{fpm} = K \times \sqrt{P_{velocity}}$$

Where K is a proportionality constant or correction factor specific to the AFMA.

Variations of the above equation are:

For a "pure" pitot tube:

$$\text{fpm} = 4500 \times \sqrt{P_{velocity}} \text{ (at standard conditions)}$$

For other manufacturers AFMAs:

$$\text{fpm} = K \times 4500\sqrt{P_{velocity}}$$

For yet other manufacturers AFMAs:

$$\text{fpm} = 4500\sqrt{P_{velocity}/K}$$

Pitot Tube AFMA – "K Factor" Example

You need to set the PV high and low range on your return air SLDC, but you do not have a configuration checksheet and there is no documentation on the flow sensor

1. Step 1. Obtain basic information:

   You determine that the DPT (that senses velocity pressure) is 0-0.5 iwc

   You determine that know that you have a Dieterich "Airbar 26" flow sensor

   You determine that the size of the duct where the Airbar 26 is located is 24 x 36 in.

2. Step 2. You call Dieterich Company and tell them the above information and ask them for their velocity equation (including the K factor)
3. Step 3. They tell you:

   $$\mathbf{fpm} = \mathbf{1097} \times \mathbf{K} \times \sqrt{\mathbf{P_{velocity}} / \rho}$$

   K = 0.6835 for your duct dimensions

   ρ = density of air = 0.075 lb/cfm (at standard conditions)

4. Step 5. Calculate fpm from the Dieterich equation at the maximum possible DPT flow signal (0.5 iwc):

   $$\text{fpm} = 1097 \times 0.6835 \times \sqrt{0.5\text{iwc}/0.07649}$$

   fpm = 1917 fpm

5. Step 6. Calculate the PV High range (cfm) of the SLDC:

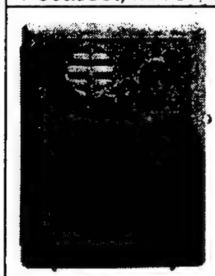
   PV High CFM = fpm x duct area

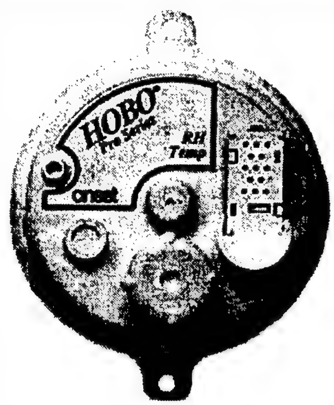
   PV High CFM= 1917 x (24 x 36 in. / 144) = 11,502 cfm

7 Using Dataloggers

Portable miniature data loggers can be used to quickly and easily diagnose short-term performance of HVAC equipment and the spaces they serve. Measurements include; temperature, relative humidity, motor status, and lighting levels. If the lighting system is controlled by occupancy sensors, the loggers can also be used to determine if the lighting systems are turning off or not during unoccupied hours. Brief descriptions of the various models and their capabilities are provided in the figures below.

Onset's BoxCar software program is required to use the HOBO loggers. The BoxCar program comes in two versions. BoxCar 3.6 ($14; Windows 3.1x or Windows 95/98/NT) allows the user to set up each logger, using a computer interface cable, by selecting sampling intervals, setting start times and memory modes, verifying logger operation before "launching" the logger, synchronizing logger clock to computer clock, and checking battery status. Data collected by the logger is downloaded back to the computer using the software and cable. The data can then be viewed in tabular and graphical format in BoxCar 3.6, or it can be exported to a spreadsheet data file. BoxCar Pro 4.0 ($95; Windows 95/98/NT4) is a more powerful enhanced version of BoxCar 3.6 with additional features for graphing, data analysis, data export, and management of multiple loggers. As an example, the additional graphing capabilities allow the user to compare multiple parameters on one graph, which can include data from multiple loggers or successive deployments. More information on the HOBO's and BoxCar software is available from:

Onset Computer Corporation P.O. Box 3450 Pocasset, MA 02449-3450	Tel.: (800) 564-4377 Fax: (508) 759-9110 Email: sales@onsetcomp.com Internet: www.onsetcomp.com
 Relative Humidity/ Temperature/Light Intensity/ External Input Model	HOBO H8 Series These come in five models: single-channel (temperature, $59); 2-channel (temperature, external, $65); 2-channels (temperature/ RH, $85); 4-channels (temperature, RH, 2x external, $95); and 4-channels (temperature, RH, light intensity, external, $95). These loggers can record up to 7,943 measurements at sampling intervals ranging from 0.5 seconds up to 9 hours. Models with external input can accept sensors to measure temperature, AC current, 4-20 mA, and 0-2.5 Volts DC. Ranges: Temperature (-4ºF to +158ºF) Relative Humidity (25% to 95%) Light Intensity (2 to 600 footcandles) Dimensions: 2.4 x 1.9 x 0.8 in.

 Motor On/Off AC-Field Sensor Model	HOBO H6 Series The H6 loggers record when devices change between on and off or open and closed. The time, date, and state is recorded for each change; capacity is 2,000 state changes. These come in four models: state (open/closed, contact closure, $69); light on/off (light sensor, $69); motor on/off (vibration sensor, $69); and motor on/off (AC-field sensor, $69). Specifications: Motor on/off AC-field sensor magnetic field threshold -2 Gauss at 60 Hz; AC motors drawing 1 A or more Motor on/off vibration sensor vibration threshold -0.05 G to 0.5 G at 60 Hz Light on/off threshold adjustment range 10 to 300 footcandles for fluorescent light; about ten times greater for incandescent light State open/closed, contact closure closed [¼ in.; open (¾ in. contact input via passive relay switch or contact closure Dimensions: 2.4 x 1.9 x 0.8 in.
 Temperature/Relative Humidity Model	HOBO H8 Pro Series These loggers are weatherproof although the model with a RH sensor does require protection from rain or direct splashing. Three models are available: 1-channel (temperature, $129); 2-channel (temperature, RH, $159); and 2-channel (temperature, external temperature, $169). The loggers can record 65,291 standard-resolution measurements or 32,645 high-resolution measurements at sampling intervals ranging from 0.5 seconds to 9 hours. Ranges: Internal Temperature (-22 °F to +122 °F) External Temperature (-40 °F to +212 °F) Relative Humidity (0% to 100%) Dimensions: 4 x 3.2 x 2 in.

For more complex data measurements, Architectural Energy Corporation's MicroDataLoggers and ENFORMA software (starting at $1,495) collects and analyzes system-wide HVAC, controls, and lighting performance data over time. The user enters a basic description of the HVAC or lighting systems to be diagnosed into the program, which then automatically determines where each logger should be located, indicates the sensors needed for each logger, and programs the loggers to get time-synchronized building system data. ENFORMA then analyzes the data and provides over 140 diagnostic plots that can identify significant HVAC, building comfort, lighting, or controls problems. This information can be used to determine energy use baselines, verify lighting retrofit savings, commission or decommission building systems, and optimize building operation. The ENFORMA/MicroDataLogger combination provides a much more powerful diagnostic tool than the Onset software and dataloggers, but also requires more technical knowledge and effort to use. For more information on the MicroDataLoggers and ENFORMA software, contact:

Architectural Energy Corporation
2540 Frontier Avenue, Suite 201
Boulder, CO 80301
Tel.: (303) 444-4149 E-mail: aecinfo@archenergy.com
Fax: (303) 444-4304 Internet: http://www.archenergy.com

8 O&M Mechanics Role Beyond O&M

Introduction

HVAC control technology can be very complex. There is a multitude of commercially available HVAC control hardware, software, and firmware technologies. It is nearly impossible for an O&M staff or staff person to become proficient with all the technologies particularly in light of reduced manpower and resources faced by most Army installations. To be successful we have no choice but to "work smarter."

From design, to construction, to acceptance by the owner and O&M staff, any number of things can go wrong with a new or retrofitted HVAC and/or control system. While it is not the owner's or O&M staff's ultimate responsibility that a properly functioning HVAC and control system be turned over to the government it is in our best interest to assist with this process when and where possible.

The Corps of Engineers is aware of the challenges of designing and constructing HVAC and control systems. As an aid meeting this challenge the use of CEGS-15995 "HVAC Systems Commissioning" is becoming more common place. Commissioning efforts including the pilot program developed by Louisville District are evolving. The Louisville District program is an intensive effort to close the design loop by involving the system designers in the acceptance process whereby the designers participate in system commissioning including inspections and functional performance testing.

Design and construction activities that the O&M staff should be aware of and participate in are described here where the ultimate goal is government acceptance of a properly functioning HVAC and control system. A properly functioning system requires much less post-acceptance maintenance attention than an improperly functioning system.

Commissioning

HVAC system commissioning is process that starts early in the design phase consisting of many activities leading to government acceptance of a properly

functioning HVAC and control system. Key elements of the commissioning process of particular interest to the O&M staff:

- BCOE (Biddability, Constructability, Operability and Environmental) review
- Performance Verification Testing
- Functional Performance Testing
- O&M documentation
- Training.

BCOE Review

BCOE (Biddability, Constructability, Operability and Environmental) review is an early review of the HVAC system design and bid specifications before construction contract bid solicitation. QV personnel and O&M staff should perform a BCO review. It is strongly recommend that BCOE review comments generated by the O&M staff be written clearly and concisely in memo format and submitted to your shop foreman. Include your name and telephone number.

Performance Verification Testing (PVT)

Performance verification testing (PVT), according to CEGS-15950 and CEGS-15951 "HVAC Control Systems," ordinarily accomplished by confirming that each system performs according to the specified sequence of operation. The PVT a means by which the Government determines if it should accept the HVAC control system. Usually the contractor is required to perform a PVT on each and every control system and submits a report to the government describing the results. It is advisable to double check the contractors PVT. Typical PVT activities include:

1. Step through the sequence of control.

2. Confirm proper operation of time clock, including vent delay, occupied and unoccupied modes.

3. Confirm that posted instructions are posted and complete.

4. Confirm that field devices are correctly located and installed to ensure that the control system will perform correctly.

5. Confirm that the "normal" (NO/NC) positions of devices are as specified.

6. Confirm proper operation of actuators by modulating each one over its specified actuation range (as shown in the Equipment Schedule). Visually inspect each as it moves.

7. Confirm that the Mixed Air/Economizer controller operates as specified.

8. Confirm that the Outside Air Temperature controller resets the setpoints of the applicable controller(s) as specified and turns pumps on and off as specified (usually based on the outside air temperature).

9. Confirm that each control loop operates properly by observing the process variable, controller setpoint, and output under automatic control.

10. Simulate a smoke alarm and confirm that the control system operates as specified.

11. Simulate a high static pressure alarm and confirm that the system operates as specified.

12. Confirm that the filter differential pressure switch setpoint has been set and operates as specified.

13. Confirm that the control panel Enable/Off switch shut downs the system as specified.

14. Confirm that the control panel Auto/Override Switch starts the HVAC system as specified.

Functional Performance Testing (FPT)

Functional Performance Testing (FPT) is similar to the Performance Verification Testing described above except the FPT covers the HVAC system in addition to the controls. FPT activities are described in CEGS-15995 "HVAC System Commissioning" and includes checklists for inspection activities and verification (actual testing) activities including:

- Pre-commissioning checklists
- Functional Performance Test (FPT) checklists.

FPT is slightly beyond the scope of this manual, but very similar to the PVT activities described above. As a practical matter, a good controls PVT can negate the need for a controls FPT because they are at least somewhat redundant.

O&M Documentation and Training

Commissioning is not complete until the operations and maintenance personnel who will be responsible for system operation have been adequately trained and have received all necessary documentation required for the maintenance of the equipment. Contract documents will usually require the contractor to provide O&M Manuals for each installed system and training based on these manuals. O&M manuals ordinarily are required to be in booklet form and include:

- Step-by-step procedures for start-up, operation, shut-down. This usually consists of the sequence of operation and miscellaneous manufacturer manuals.
- All detailed drawings (including posted instructions).
- Equipment data for each control device showing the unique identifier, manufacturer name, part number and specifications.
- Configuration checksheet for each controller and time clock.
- Manufacturers operation manuals for the digital controllers, time clock, air compressor, and other equipment
- Maintenance procedures for all control devices/equipment including installation and calibration data
- Maintenance checklist for each control system
- Recommended repair methods (field, factory, replace)
- Spare parts data and recommended tool kits.

The contractor is usually responsible for providing training within 30 days of system completion (PVT) and usually consists of:

- 32 hours of instruction
- One training manual per student.

Glossary

Note: The terms and symbols cited in this glossary were originally published in Technical Instruction (TI) 810-11, *Heating, Ventilating and Air Conditioning (HVAC) Control Systems* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], 30 November 1998).

=:	Equal to
<:	Less Than
>:	Greater Than
A:	Ampere
AAD:	Auxiliary Actuator Driver
AC:	Alternating Current
Accuracy:	The degree of conformity of an indicated value to a recognized accepted standard value.
Actuator:	A device that, either electrically or pneumatically operated, changes the position of a valve or damper.
AD:	Control Damper
AFMA:	Air-Flow Measurement Station
AHU:	Air-Handling Unit
AI:	Analog Input
Analog:	A signal type representing a system variable (such as temperature, humidity, or pressure) that can be measured continuously over a scale.
AO:	Analog Output
AUTO:	Automatic

Automatic Temperature Control:	A local loop network of pneumatic or electric/electronic devices that are interconnected to control temperature.
AUX:	Auxiliary
Auxiliary Actuator Driver:	An actuator circuit that can be used to control a separate actuator.
Bias:	A single-loop digital controller function which maintains a fixed difference in engineering units between controller setpoint and the remote setpoint signal to the controller in engineering units.
BLR:	Boiler
C:	Common
Cavitation:	A phenomenon that results in valve damage from too great a pressure drop through a valve.
CB:	Circuit Breaker
CC:	Cooling Coil
CDHR:	Condenser, Hydronic Return
CDHS:	Condenser, Hydronic Supply
CFM:	Cubic Feet Per Minute
CH:	Chiller
CLK:	Time Clock
Closed Loop System:	Control system configuration that allows system feedback.
COND:	Condenser
Controlled Device:	The instrument that receives the controller's output signal and regulates the controlled process.
Controlled Variable:	The temperature, humidity, or pressure value to whose variations the controller responds. Controlled variable is also called process variable.

Controller: The instrument that measures the controlled variable and responds by producing an output signal that holds the controlled variable within preset limits.

Controller Feedback: The change in the controller's output in response to a measured change in the controlled variable that is transmitted back to the controller's input.

Control Point: The actual value at which a controller is holding a process variable.

Controller Configuration: Information manually entered through a controller keyboard which selects built-in controller options and sets controller parameters.

Control Point Adjustment (CPA): Adjustment of a controller's setpoint. The control point value may vary from the setpoint due to load offset. Control point adjustment can be accomplished by a signal generated from a local adjustment device, by a signal generated from a remote location, or by means of software.

Controls: Devices that govern the performance of a system.

COOL: Cooling

CPA: Control Point Adjustment (Remote Setpoint Adjustment)

C.T.: Cooling Tower

CUH: Cabinet Unit Heater

C_v: The liquid flow coefficient of a valve that has the units of gpm per psid and is used to select the valve for a required flow in the open position at a calculated pressure drop.

D: Derivative Control Mode

DA: Damper Actuator

DC: Direct Current

DD:	Dual Duct
DDC:	Direct Digital Control
Deadband:	A range of thermostat output signal, between the shutoff of heating and start of cooling, in which no heating or cooling energy is used.
DEG:	Degree
Derivative (D) Mode:	Control mode in which the output is proportional to the rate of change of the input.
Deviation Contact (DEV):	A single-loop digital controller output contact that can be configured to respond to a given difference between the setpoint of the controller and the process variable input signal.
DI:	Digital Input
DIA:	Diagram
Differential:	The difference in values of the controlled variable that will cause a two-position controller to change its output.
Differential Pressure:	The difference between the static pressures measured at two points in an HVAC system.
Direct Acting:	An output signal that changes in the same direction as the controlled or measured variable. An increase in the controlled or measured variable results in an increase in the output signal.
DMPR:	Damper
DO:	Digital Output
DPI:	Differential-Pressure Gauge
DPDT:	Double-Pole, Double-Throw
DPS:	Differential-Pressure Switch
DPST:	Double-Pole, Single-Throw

DPT:	Differential-Pressure Transmitter
DX:	Direct-Expansion Coil
EA:	Each
EC:	Economizer Controller
ECON:	Economizer
Economizer Mode:	The control system mode of operation in which outside air is used for free-cooling of building spaces.
EF:	Exhaust Fan
EMCS:	Energy Monitoring and Control Systems used in military facilities for supervisory control of HVAC control systems and energy related monitoring and control functions.
EP:	The acronym for a two-position electric-solenoid-operated 3-way air valve. (Electric to pneumatic.).
Equipment Schedule:	A listing of control devices by loop function, unique identifier, setpoints, ranges, and other parameters.
ES:	End Switch
EXH:	Exhaust
F:	Fahrenheit, Friday
FC:	Flow Controller
FCU:	Fan-Coil Unit
FE:	Flow-Sensing Element
FLTR:	Filter
FPM:	Feet Per Minute
FPS:	Feet Per Second
Free-Cooling:	Cooling without mechanical refrigeration.
FT:	Flow Transmitter

FTR:	Finned-Tube Radiator
Function Module:	A device for performing a control-loop function between the transmitter and the controller or between the controller output and the controlled devices.
Gain:	The amount of change in controller output per unit change of controller input.
GC:	Glycol Coil
GPM:	Gallons Per Minute
H:	High
HC:	Heating Coil
HD:	Head
Heat:	Heating
HFER:	Humidifier
HL:	High Limit
HOA:	Hand-Off-Automatic
HP:	Horsepower
HPS:	High-Pressure Steam
HR:	Heat Recovery
HRC:	Heat-Recovery Coil
HRS:	Hours
HS:	Manual Switch
HTHW:	High-Temperature Hot Water
HVAC:	Heating, Ventilating, and Air Conditioning
HWS:	Hot Water Supply
HX:	Heat Exchanger (Converter)

Hydronic: A term used to describe HVAC systems using liquid heating and cooling media.

HZ: Cycles Per Second (Hertz)

I: Integral Control Mode

IH: Infrared Heater

Input Signal: The variable signal, received by an instrument, which provides that instrument with a means of changing its output signal.

INV: Signal-Invertor Module

IO: Input/Output

IP: The acronym for a current to pneumatic signal transducer. (I for current and P for pneumatic.)

Integral (I) Mode: Control mode in which the output is proportional to the time integral of the input; i.e., the rate of change of output is proportional to the input.

IV: Inlet Vane

K : The liquid flow coefficient of a valve that has v the units of m /hr per 100 kPa pressure drop 3 and is used to select the valve for a required flow in the open position at a calculated pressure drop.

kPa: Kilo-Pascal

L1, L2, N: Control-Power Lines and Neutral

L: Low

Ladder Diagram: A diagram that shows the electrical control-logic portion of a control system.

LD: Loop Driver

LDR: Ladder

Linearity:	A relation such that any change of input signal is accompanied by a similar output change that is directly proportional to the input.
Local-Loop Control:	The local pneumatic or electric/electronic controls for any system or subsystem.
LOC:	Location
Loop Driver:	A device used in control loops to assure that the single-loop digital controller will not be required to drive a loop with a greater impedance than 600 ohms.
LPS:	Low-Pressure Steam
L/s:	Liters per second
LTHW:	Low-Temperature Hot Water
M:	Main Air, Motor, Monday
MA:	Milliamp
MAN.:	Manual
Manual Reset:	The act of manually restoring control-circuit electrical continuity after the circuit has been opened by a safety device. A feature of the single-loop digital controller that allows manual adjustment of the analog output signal when proportional mode control is used without integral mode control or derivative mode control.
Measured Variable:	The uncontrolled variable (such as temperature, relative humidity, or pressure) sensed by the measuring element.
Microprocessor Controller:	A microprocessor-based controller (non-analog in processing its internal signals) that performs a dedicated function and does not require software programming.
MIN:	Minimum

Minimum-Position Switch:	A manual switch used to set the position of mixing plenum control dampers to assure that the minimum quantity of outside air is introduced by an HVAC system.
MO1, MO2:	Magnetic-Starter Holding coil
Modulating Control:	Control achieved by gradually changing a controller analog output signal to an actuator in response to a change in a sensed variable.
MPS:	Minimum-Position Switch
M/S:	Meters per second
MZ:	Multizone
Normally Closed:	A controlled device that closes when its power supply or input signal is removed.
Normally Open:	A controlled device that opens when its power supply or input signal is removed.
Normal Mode:	The usual or expected operating condition.
OA:	Outside Air
OCC:	Occupied
Offset:	The difference between the setpoint of a controller and the actual control point of the controlled variable, caused by changes in load.
OL:	Overload
Open-Loop System:	Control-system configuration that does not have system feedback.
OUT:	Output
Output Signal:	A signal produced in response to an input.
P:	Proportional Control Mode
Pa:	Pascal

Parameter: Information and values to be used in configuring a microprocessor controller for its purpose in the control-system application.

PB: Proportional Band

PC: Outside-Air Preheat Coil, Pressure Controller

PE: Pneumatic-Electric Switch

PH: Phase

PI: Pressure Indicator (Gauge) or Proportional-Plus-Integral Control Mode

PID: Proportional-Plus-Integral-Plus Derivative

Control Mode

PL: Pilot Light

Positive Positioner: A mechanical device that measures actuator position and control signal value and sends main air to the actuator to maintain the correct position for the signal.

PP: Positive Positioner

Process Control: The science of regulating variables by measuring, processing, and manipulating process variables coupled to the regulated variables.

Process Variable: See Controlled Variable.

Process Variable Contact (PV): A single-loop digital controller output contact that can be configured to respond to a given value of the process variable input signal.

PROP: Proportional

Proportional Band: A controller parameter setting which determines the change in the number of engineering units of a process variable input signal that will produce a full-scale change of the controller analog output signal.

Proportional (P) Mode: Control mode in which there is a continuous linear relationship between the input and the output.

Proportional-Integral (PI) Mode: Control mode in which the output is proportional to a linear combination of the input plus a value proportional to the time integral of the error between setpoint and control point.

Proportional-Integral-Derivative (PID) Mode: Control mode in which the output is a value proportional to the input, plus a value proportional to the time integral of the error between setpoint and control point plus a value proportional to the time rate of change of the error.

PSI: Pounds Per Square Inch

PSIA: Pounds Per Square Inch, Absolute

PSID: Pounds Per Square Inch, Differential

PSIG: Pounds Per Square Inch, Gauge

PV: Process Variable

R: Relay

RA: Return Air

Range: The upper and lower limits of the value of a

variable.

Ratio: A single-loop digital controller feature which multiplies the remote setpoint input signal to the controller by a constant and uses the resulting value as the controller setpoint.

Relay: An electric device that changes the position of its contacts when its coil is energized.

Remote Setpoint: See Control Point Adjustment.

Resistance Temperature Detector (RTD): A device whose resistance changes linearly as a function of temperature.

REV: Reverse-Acting

Reverse Acting:	An output signal that changes in the opposite direction from the controlled or measured variable. An increase in the controlled or measured variable results in a decreased output signal.
RF:	Return Fan
RH:	Relative Humidity
RHC:	Relative-Humidity Controller, Reheat Coil
RHT:	Relative-Humidity Transmitter
RHY:	Humidity Loop Device
SA:	Supply Air
SAT:	Saturday
Schematic:	A diagram that shows the relationship of control devices to control loops and shows the relationship of control loops to systems.
SCIM:	Standard Cubic Inches Per Minute
Self-Tuning:	A single-loop digital controller feature that, when selected, commands the controller to calculate the optimal proportional, integral and derivative mode constants for the process being controlled and to use the calculated constants for control.
Sensitivity:	The unit change in controller output per unit change in the controlled variable. Usually expressed in psi or milliamps per degree, cfm, etc.
Sensing Element:	A device used to detect or measure physical phenomena.
Sequence of Operation:	A narrative that describes the actions of control devices such as valves and dampers as the process variable changes in a given direction, such as on a temperature, humidity, or pressure increase.
Setpoint:	The desired value of the controlled variable at which the controller is set.

SF:	Supply Fan
SHLD:	Sunshield
Signal Inverter:	A device that linearly converts a 4 to 20 milliampere input signal to an output signal of 20 to 4 milliamperes.
Signal Selector:	A device that selects the highest or the lowest of its input signals as its output signal. SLDC Single Loop Digital Controller - A controller that accepts analog input signals, processes the signals digitally according to the controller configuration, and, as a result, produces analog output and two-position output signals.
SMK:	Smoke Detector
Smoke Detector:	A generic term for devices that are used to operate safety circuits on the detection of smoke or products of combustion.
SP:	Static Pressure
S.P.:	Setpoint
Span:	The number of engineering units between the extremes of a calibration range.
SPRG:	Spring Range
Spring Range:	The range over which the input signal to a controlled device must change to move the device from one extreme to the other.
SPT:	Static-Pressure Transmitter
SQCR:	Sequencer
STM:	Steam
SUN:	Sunday

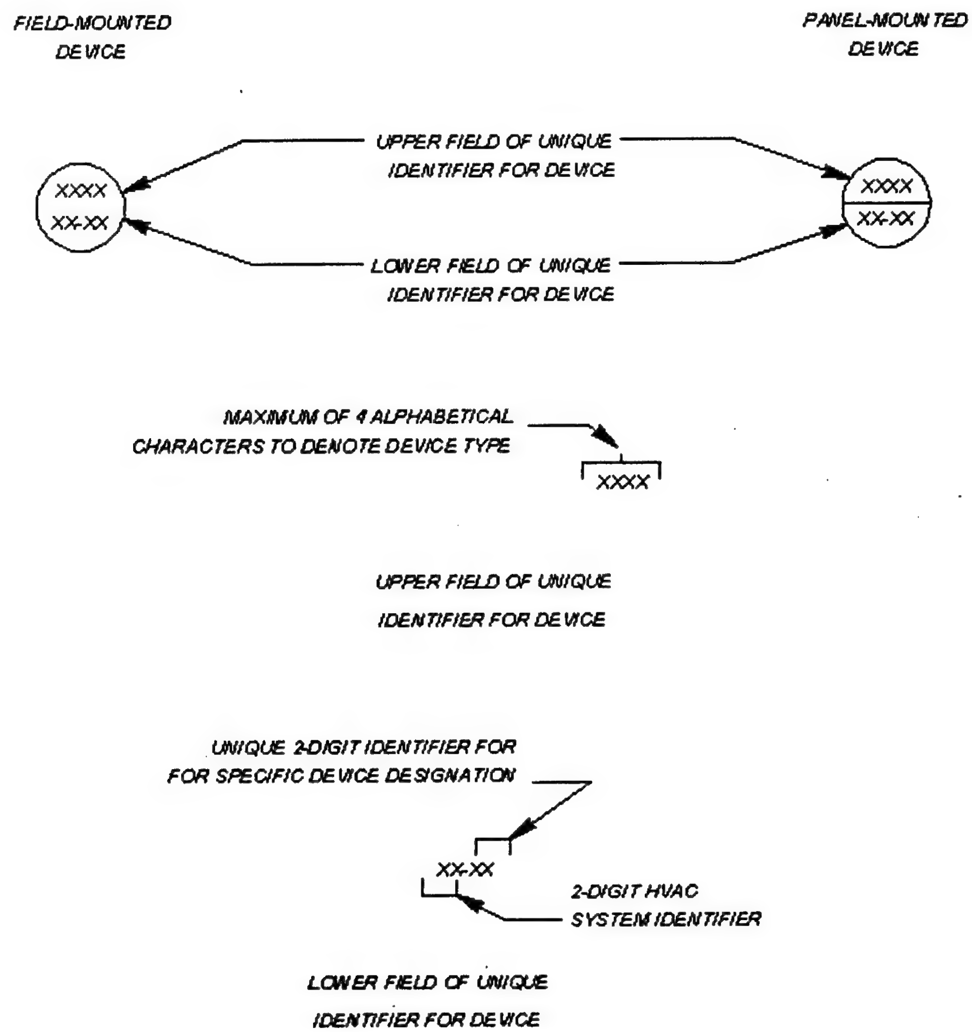
Sunshield:	A device installed outdoors on the surface of a building to house outside-air temperature-sensing elements and to shield them from direct exposure to sun's radiation.
Supply Pressure:	Gauge pressure of the compressed air supplied to a pneumatic control system, usually 140 kPa (20 psig).
Supply Voltage:	Voltage of the electric energy supply to an electric/electronic control system.
Surge Protection:	Methods of protecting signal wiring and power wiring circuits from damage by electrical voltage and current overrange due to such factors as lightning strikes.
System Feedback:	System's response to the controller's action in changing the value of a controlled variable, as transmitted back to the controller.
SZ:	Single Zone
T:	Modulating Thermostat, Tuesday
TC:	Temperature Controller
TDR:	Time Delay Relay
TE:	Temperature-Sensing Element
TEMP:	Temperature
Terminal Unit:	A unit through which heating or cooling is distributed to the conditioned space. Terminal units include radiators, unit heaters, gas-fired infrared heaters, variable-air-volume boxes, duct heating coils, and fan-coil units.
TH:	Thursday
Thermostat:	A device that senses temperature and changes its output as a result of temperature changes.

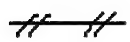
Throttling Range:	The portion of the instrument range of a controlled variable required to move the controlled device from one extreme to the other.
TI:	Thermometer
Time Clock:	A device that changes the positions of its output contacts according to a timing schedule.
Transmitter:	A transducer that senses the value of a variable and converts this value into a standardized transmission signal.
TS:	Non-Modulating Space Thermostat or
Aquastat	
TSL:	Low-Temperature-Protection Thermostat or
Nightstat, Non-modulating	
TSP:	Temperature-Setpoint Device
Tuning:	The process of finding the control-mode constants the use of which results in the stable control of a process at or near the controller setpoint.
TuP:	Microprocessor Room Thermostat
TT:	Temperature Sensor and Transmitter
Two-Position Control:	Control achieved by switching a controller output signal on and off in response to a change in a sensed variable.
TY:	Temperature Loop Device
UH:	Unit Heater
Unique Identifier:	An alphanumeric identifier that consists of: 1) an abbreviation for the type of device; and 2) a number made up of an HVAC-system number and a serial number for the device.
UNOCC:	Unoccupied

VAV:	Variable Air Volume
VFDU:	Variable-Frequency Drive Unit
VLV:	Valve
W:	Wednesday
WTR:	Water
X1, X2:	transformer Power, Hot and Ground
X:	Times (Multiplication)
XMFR:	Transformer

This section contains the symbols which will be used for HVAC control system drawings produced in accordance with this Engineering Instruction.

Each symbol will be referenced to a unique identifier, which will use the following format:

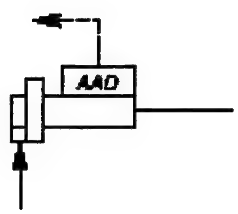

FIELD-MOUNTED DEVICE
PANEL-MOUNTED DEVICE
UPPER FIELD OF UNIQUE IDENTIFIER FOR DEVICE
XXXX
XX-XX
LOWER FIELD OF UNIQUE IDENTIFIER FOR DEVICE
MAXIMUM OF 4 ALPHABETICAL CHARACTERS TO DENOTE DEVICE TYPE
XXXX
UPPER FIELD OF UNIQUE IDENTIFIER FOR DEVICE
UNIQUE 2-DIGIT IDENTIFIER FOR FOR SPECIFIC DEVICE DESIGNATION
XX-XX
2-DIGIT HVAC SYSTEM IDENTIFIER
LOWER FIELD OF UNIQUE IDENTIFIER FOR DEVICE



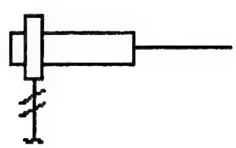
PNEUMATIC LINE

ELECTRIC LINES (LADDER DIAGRAMS
ANDSCHEMATICS)

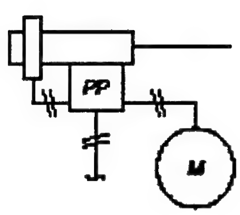
ELECTRONIC SIGNALS (SCHEMATICS)



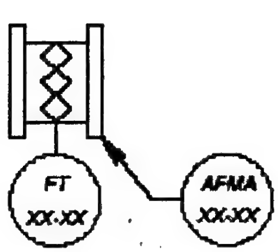
ACTUATOR, ELECTRIC
OR ELECTRONIC



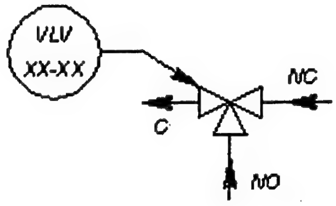
ACTUATOR, PNEUMATIC



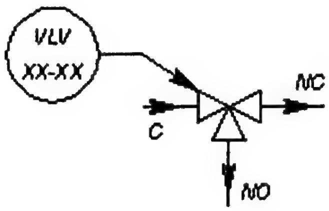
ACTUATOR, PNEUMATIC
WITH POSITIVE POSITIONER



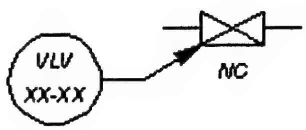
AIR-FLOW MEASURING STATION
AND TRANSMITTER



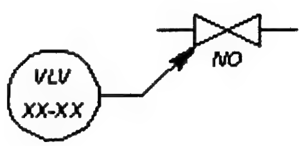
VALVE, 3-WAY MIXING



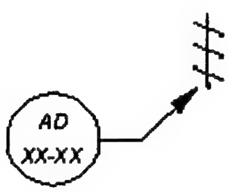
VALVE, 3-WAY DIVERTING



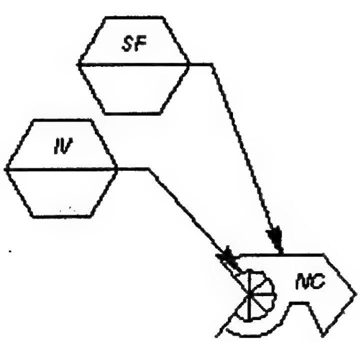
2-WAY VALVE, NORMALLY CLOSED



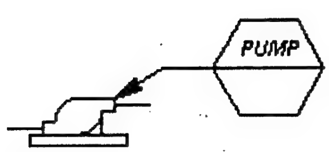
2-WAY VALVE, NORMALLY OPEN



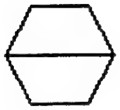
DAMPER, PARALLEL-BLADE WITH SEALS



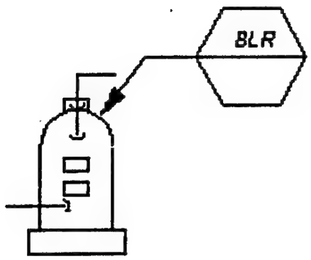
FAN, WITH INLET GUIDE VANES



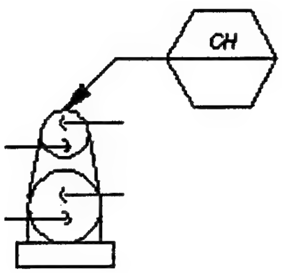
PUMP



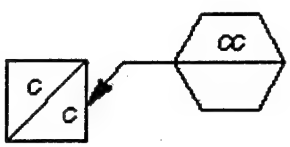
HVAC EQUIPMENT IDENTIFIER



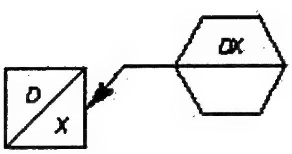
BOILER



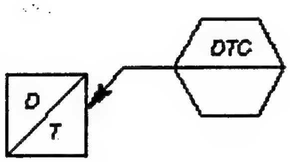
CHILLER



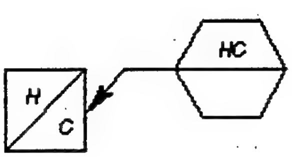
COIL, COOLING



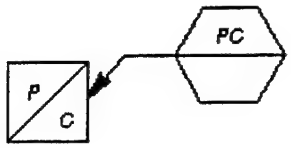
COIL, COOLING, DIRECT-EXPANSION



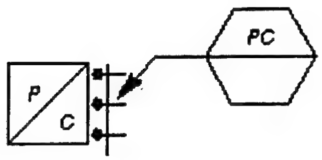
COIL, DUAL TEMPERATURE



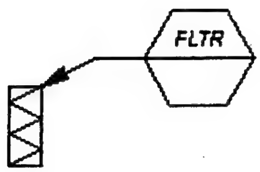
COIL, HEATING



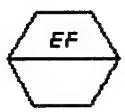
COIL, OUTSIDE-AIR PREHEAT



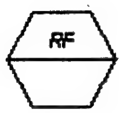
COIL, OUTSIDE-AIR PREHEAT
FACE & BYPASS DAMPER



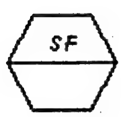
FILTER



EXHAUST FAN

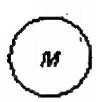


RETURN FAN

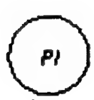


SUPPLY FAN

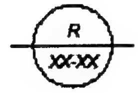
THERMOWELL



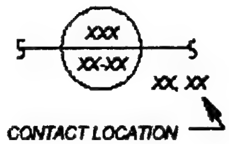
MAIN AIR



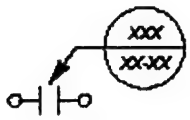
FIELD-MOUNTED PRESSURE GAUGE



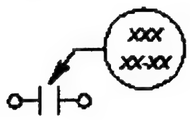
RELAY COIL



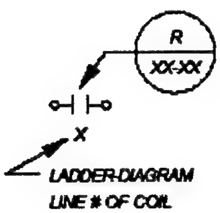
RELAY-COIL OR DEVICE OPERATING CIRCUIT



PANEL-DEVICE CONTACT



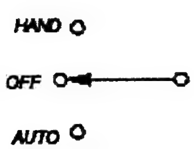
FIELD-DEVICE CONTACT



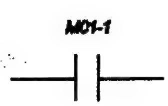
RELAY CONTACT

MAINTAINED-CONTACT INTERLOCKED SWITCHES

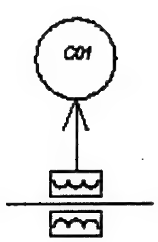
MOMENTARY SWITCH



MAGNETIC STARTER LOCAL CONTROL SWITCH



MAGNETIC STARTER POWER CONTACT



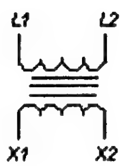
CURRENT SENSING RELAY

MAGNETIC STARTER CIRCUIT BREAKER

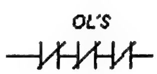
MAGNETIC STARTER CONTROL-CIRCUIT FUSE

MOTOR

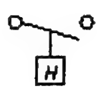
MAGNETIC STARTER HOLDING COIL



MAGNETIC STARTER CONTROL CIRCUIT TRANSFORMER

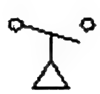


MAGNETIC STARTER OVERLOADS



HUMIDITY SWITCH CONTACT
(MAKES ON HUMIDITY INCREASE)

HUMIDITY SWITCH CONTACT
(BREAKS ON HUMIDITY INCREASE)



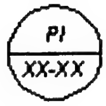
PRESSURE SWITCH CONTACT
(MAKES ON PRESSURE INCREASE)

PRESSURE SWITCH CONTACT
(BREAKS ON PRESSURE INCREASE)

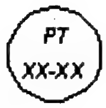
TEMPERATURE SWITCH CONTACT
(MAKES ON TEMPERATURE RISE)
(BREAKS ON TEMPERATURE FALL)

TEMPERATURE SWITCH CONTACT
(BREAKS ON TEMPERATURE RISE)
(MAKES ON TEMPERATURE FALL)

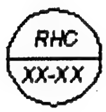
CLK XX-XX	TIME CLOCK
DPS XX-XX	DIFFERENTIAL PRESSURE SWITCH
DPT XX-XX	DIFFERENTIAL PRESSURE TRANSMITTER
EC XX-XX	ECONOMIZER CONTROLLER
EP XX-XX	ELECTRIC-SOLENOID-ACTUATED PNEUMATIC VALVE
FC XX-XX	FLOW CONTROLLER
FT XX-XX	FLOW TRANSMITTER, DUCT-MOUNTED
FS XX-XX	FLOW SWITCH
IP XX-XX	CURRENT-TO-PNEUMATIC TRANSDUCER
LD XX-XX	LOOP DRIVER
MPS XX-XX	MINIMUM-POSITION SWITCH
PC XX-XX	PRESSURE CONTROLLER



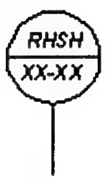
PANEL-MOUNTED PRESSURE GAUGE



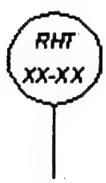
PRESSURE TRANSMITTER



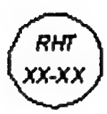
RELATIVE HUMIDITY CONTROLLER



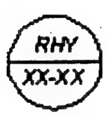
HI-LIMIT HUMIDISTAT, NON-MODULATING



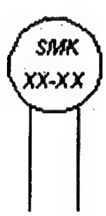
RELATIVE HUMIDITY TRANSMITTER, DUCT-MOUNTED



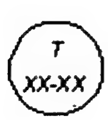
RELATIVE HUMIDITY TRANSMITTER, SPACE-MOUNTED



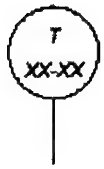
SIGNAL SELECTOR, HUMIDITY CONTROL LOOP



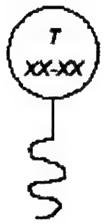
SMOKE DETECTOR, DUCT-MOUNTED



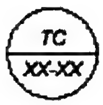
MODULATING SPACE THERMOSTAT



MODULATING DUCT THERMOSTAT, NON-AVERAGING

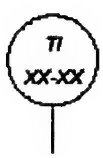


MODULATING DUCT THERMOSTAT, AVERAGING

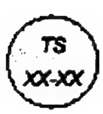


TEMPERATURE CONTROLLER

THERMOMETER, AVERAGING



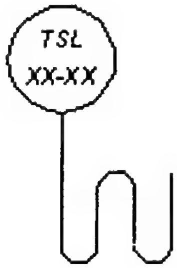
THERMOMETER, NON-AVERAGING



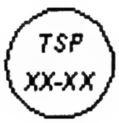
NON-MODULATING SPACE THERMOSTAT,
(MAKES/BREAKS CONTACTS ON TEMPERATURE RISE)

NON-MODULATING SPACE THERMOSTAT,
(MAKES CONTACT ON TEMPERATURE RISE)

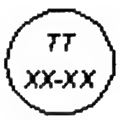
NIGHT THERMOSTAT, NON-MODULATING
SPACE THERMOSTAT, (BREAKS CONTACT
ON TEMPERATURE RISE)



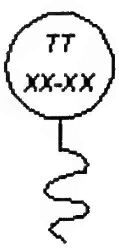
THERMOSTAT, LOW-TEMPERATURE PROTECTION



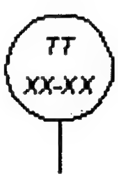
MANUAL TEMPERATURE SETPOINT DEVICE



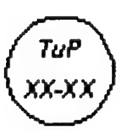
SPACE TEMPERATURE TRANSMITTER



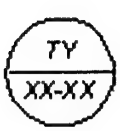
TEMPERATURE TRANSMITTER, AVERAGING



TEMPERATURE TRANSMITTER, DUCT-MOUNTED



MICROPROCESSOR-BASED SPACE THERMOSTAT



SIGNAL SELECTOR, TEMPERATURE CONTROL LOOP

Appendix A: Typical Setpoints and PID Tuning Constants for Common HVAC Control Loops

General

The controller settings described here apply primarily to single-loop digital controllers and are provided as guidelines only. Control setpoints ordinarily are designer selections and should be shown/found on the control system "Equipment Schedule" drawing. PB and I may need to be adjusted, beyond the initial settings shown below, as part of the controller tuning process.

- Setpoint (**SP**) is the value of a process variable (PV) that a control loop is to maintain.
- Throttling Range (**TR**) is the amount of change in the process variable that causes the controller output to move full range (4-20mA). Suggested values are shown below.
- Proportional Band (**PB**) tuning constant, in units of percent of sensor span, to be entered into the controller depends on the TR for the application and is calculated as:

  PB = TR x 100 / SS

- Sensor Span (**SS**) is the calibrated range (in engineering units) of the 4-20 mA transmitter assembly. For example, the sensor span of a 40 to 140 °F temperature transmitter is 100 °F.
- Integral (**I**) tuning constant is shown in units of seconds per repeat.
- Derivative (**D**) tuning constant = zero (do not need it in HVAC control).

Preheat Coil Discharge Air Temperature Controller

SP = 40 °F

when the sensor is located in the outside air duct.

SP = 55 °F

when the sensor is located in the mixed air section, supply air duct, or when the coil is in a 100% outside air system (i.e., when there is no return duct).

TR = 25 °F, I = 60 seconds

Cooling Coil Discharge Air Temperature Controller

SP = 55 to 60 °F

which depends on the HVAC system design.

TR = 25 °F, I = 60 seconds

Heating Coil Discharge Air Temperature Controller

SP = Between 80 and 115 °

which may be automatically adjusted (reset) based on outside air temperature.

TR = 25 °F, I = 60 seconds

Mixed Air Temperature Controller

SP = 52° to 58 F

Usually set 2° to 3° F below the cooling coil discharge air temperature setpoint to compensate for the temperature rise across the supply fan.

TR = 25°F, I = 30 seconds

Dry Bulb Economizer Controller

Two conditions must be met for the Economizer Controller to activate the economizer mode:

1. *PV contact setpoint*: There must be a cooling demand as indicated by a warm return air temperature. If the return air temperature is above about 73 °F, there is a probable demand for cooling. This is the PV contact setpoint.
2. *DEV contact setpoint*: The outside air must be cool enough to supply free cooling so it is necessary for the outside air temperature to be lower than the return air temperature by a difference (DEV) great enough to ensure that the enthalpy (heat content) of the outside air is less than that of the return air. This is a design calculation based on the particular climatic location. Typical DEV contact setpoints:

- Dry climate: 1 to 2°F
- Moderate climate: 4 to 6°F
- Humid climate: 8 to 12°F.

Supply Duct Static Pressure Controller

SP = 0.8 to 1.0 iwc.

The setpoint should equal the sum of the minimum static pressure required at the inlet of the VAV terminal units and the pressure loss in the ductwork between the sensor and the most remote VAV terminal unit at the maximum air flow rate. During system balancing, the optimum setpoint can be established by lowering the setpoint value to the lowest possible setting at which the most remote VAV terminal unit will continue to function properly. A high limit static pressure sensor is often provided in the ductwork immediately downstream of the supply fan to prevent damage to the ductwork in the event of a failure in the static pressure control loop. Its setpoint depends on the duct classification.

TR = 4 iwc, I = 30 seconds

VAV Return Air Volume (CFM) Flow Controller

SP is adjusted by the flow sensor located in the <u>supply</u> air duct. The return fan flow controller subtracts (biases) a certain amount of cfm from the supply air flow sensor signal to establish the setpoint of the return fan flow controller. The controller <u>Bias</u> parameter should be set equal to the total cfm of space exhaust fans + 10% of the design supply air cfm flow (As a negative number). The <u>Ratio</u> parameter accounts for differences in flow sensor ranges and duct areas where the flow stations are installed. Ratio = (SA air sensor range / RA air sensor range) x (SA duct area / RA duct area)

TR = 2 x design supply air cfm flow, I = 30 seconds

Minimum Outside Air Volume (CFM) Flow Controller

SP = whichever is <u>larger</u>:

1. Total cfm of space exhaust fans + 10% of design supply air cfm flow

or

2. Fresh air ventilation cfm flow (based on ASHRAE standard 62)

TR = 2 x SP, I = 30 seconds

Space Humidity Controller

SP = 45 to 55 %RH

TR = 10 %RH, I = 120 seconds

Duct Humidity High Limit Controller

SP = 90 %RH, TR = 20 %RH, MR = 50% (or 12mA)

These settings cause the humidifier valve to begin to close at 80 %RH and to be full closed at 90 %RH when the valve actuation range is 10-15 psi (13.3 mA - 20 mA).

Single Zone Temperature Controller

Adjustable Setpoint = 68 °F

During the heating season and 78 °F during cooling season.

Computer rooms, critical areas of hospitals, labs, etc., setpoints will usually be maintained between 72 to 75 °F year around.

TR = 4 °F, I = 0

Night Stat

SP = 45 to 55 °F

Depending on system.

The setpoint depends on time required to achieve temperature recovery when the AHU is started back up, material storage requirements, and keeping the building warm enough prevent mechanical systems from freezing during unoccupied mode.

Heating Hot Water Temperature Controller

SP = 100 to 180 °F

This may be automatically adjusted (reset) based on outside air temperature. Boiler igniter/flame controller setpoint=180° F. Never less than 130° F.

TR = 30 °F, I = 60 seconds

Appendix B: Blank Configuration Checksheets

CONFIGURATION CHECKSHEET

Control Loop:________________

	Upper Display	Lower Display
Control Action	Act	____ (direct or reverse)
Setpoint Derived from	SPF	___ (panel or AI2)
Low limit of setpoint	SPLL	___ (adjustment lo range)
High limit of setpoint	SPHL	___ (adjustment hi range)
Setpoint	SP--	___ (not shown if AI2)
Cal for AI2 is not used		
Action for AO2	Ao-2	___ (2nd output)
Manual reset value	rStP	___ mA
Minimum controller output	AoLL	___ mA
Maximum controller output	AoHL	___ mA
Digital Input 1	dI1-	___
Digital Input 2	dI2-	___
Alarm 1 Action	AL1-	___
Alarm 1 Type	AL1t	___
Alarm 1 Offset <u>or</u> Setpoint	oFF1 <u>or</u> AL1u	___
Alarm 1 Hysteresis	Hys1	___ (deadband)
Alarm 2 Action	AL2-	___
Alarm 2 Type	AL2t	___
Alarm 2 Offset <u>or</u> Setpoint	oFF2 <u>or</u> AL1u	___
Alarm 2 Hysteresis	Hys2	___ (deadband)
Proportional band	P---	___ %
Integral value	I---	___ seconds
Derivative	d---	___ seconds
Process Variable (PV) Low Range	Lo1-	___ (sensor/TT range)
Process Variable (PV) High Range	HI1-	___ (sensor/TT range)
Communications Port type	Port	___
Address	Addr	___
Baud	bAUd	___
Protocol	PtcL	___

CONFIGURATION CHECKSHEET

Control Loop: ____

	Upper Display	Lower Display
Control Action	Act	_____ (direct or reverse)
Setpoint Derived from	SPF	____ (panel or AI2)
Low limit of setpoint	SPLL	____ (adjustment lo range)
High limit of setpoint	SPHL	____ (adjustment hi range)
Setpoint	SP–	____ (not shown if AI2)
Calibration for AI2	CAL2	2-pt
Low limit	Lo2-	(at 4mA input signal)
High limit	HL2-	(at 20 mA input signal)
Action for AO2	Ao-2	____ (2nd output)
Manual reset value	rStP	____ mA
Minimum controller output	AoLL	____ mA
Maximum controller output	AoHL	____ mA
Digital Input 1	dI1-	____
Digital Input 2	dI2-	____
Alarm 1 Action	AL1-	____
Alarm 1 Type	AL1t	____
Alarm 1 Offset or Setpoint	oFF1 or AL1u	____
Alarm 1 Hysteresis	Hys1	____ (deadband)
Alarm 2 Action	AL2-	____
Alarm 2 Type	AL2t	____
Alarm 2 Offset or Setpoint	oFF2 or AL1u	____
Alarm 2 Hysteresis	Hys2	____ (deadband)
Proportional band	P---	____ %
Integral value	I---	____ seconds
Derivative	d---	____ seconds
Process Variable (PV) Low Range	Lo1-	____ (sensor/TT range)
Process Variable (PV) High Range	HI1-	____ (sensor/TT range)
Communications Port type	Port	____
Address	Addr	____
Baud	bAUd	____
Protocol	PtcL	____

Appendix C: Temperature/Resistance Table for 100 and 1000 Ohm RTD

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
-34.4	-30	86.5	864.7
-33.9	-29	86.7	866.9
-33.3	-28	86.9	869.1
-32.8	-27	87.1	871.3
-32.2	-26	87.3	873.5
-31.7	-25	87.6	875.6
-31.1	-24	87.8	877.8
-30.6	-23	88.0	880.0
-30.0	-22	88.2	882.2
-29.4	-21	88.4	884.4
-28.9	-20	88.7	886.6
-28.3	-19	88.9	888.8
-27.8	-18	89.1	891.0
-27.2	-17	89.3	893.2
-26.7	-16	89.5	895.4
-26.1	-15	89.8	897.6
-25.6	-14	90.0	899.7
-25.0	-13	90.2	901.9
-24.4	-12	90.4	904.1
-23.9	-11	90.6	906.3
-23.3	-10	90.8	908.5
-22.8	-9	91.1	910.7
-22.2	-8	91.3	912.9
-21.7	-7	91.5	915.0
-21.1	-6	91.7	917.2
-20.6	-5	91.9	919.4
-20.0	-4	92.2	921.6
-19.4	-3	92.4	923.8
-18.9	-2	92.6	926.0
-18.3	-1	92.8	928.2
-17.8	0	93.0	930.3
-17.2	1	93.3	932.5
-16.7	2	93.5	934.7
-16.1	3	93.7	936.9
-15.6	4	93.9	939.1
-15.0	5	94.1	941.2
-14.4	6	94.3	943.4
-13.9	7	94.6	945.6
-13.3	8	94.8	947.8
-12.8	9	95.0	950.0
-12.2	10	95.2	952.1
-11.7	11	95.4	954.3
-11.1	12	95.7	956.5
-10.6	13	95.9	958.7
-10.0	14	96.1	960.9
-9.4	15	96.3	963.0
-8.9	16	96.5	965.2
-8.3	17	96.7	967.4
-7.8	18	97.0	969.6
-7.2	19	97.2	971.7
-6.7	20	97.4	973.9
-6.1	21	97.6	976.1
-5.6	22	97.8	978.3
-5.0	23	98.0	980.4
-4.4	24	98.3	982.6
-3.9	25	98.5	984.8
-3.3	26	98.7	987.0
-2.8	27	98.9	989.1

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
-2.2	28	99.1	991.3
-1.7	29	99.3	993.5
-1.1	30	99.6	995.7
-0.6	31	99.8	997.8
0.0	32	100.0	1000.0
0.6	33	100.2	1002.2
1.1	34	100.4	1004.3
1.7	35	100.7	1006.5
2.2	36	100.9	1008.7
2.8	37	101.1	1010.9
3.3	38	101.3	1013.0
3.9	39	101.5	1015.2
4.4	40	101.7	1017.4
5.0	41	102.0	1019.5
5.6	42	102.2	1021.7
6.1	43	102.4	1023.9
6.7	44	102.6	1026.0
7.2	45	102.8	1028.2
7.8	46	103.0	1030.4
8.3	47	103.3	1032.5
8.9	48	103.5	1034.7
9.4	49	103.7	1036.9
10.0	50	103.9	1039.0
10.6	51	104.1	1041.2
11.1	52	104.3	1043.4
11.7	53	104.6	1045.5
12.2	54	104.8	1047.7
12.8	55	105.0	1049.8
13.3	56	105.2	1052.0
13.9	57	105.4	1054.2
14.4	58	105.6	1056.3
15.0	59	105.8	1058.5
15.6	60	106.1	1060.7
16.1	61	106.3	1062.8
16.7	62	106.5	1065.0
17.2	63	106.7	1067.1
17.8	64	106.9	1069.3
18.3	65	107.1	1071.5
18.9	66	107.4	1073.6

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
19.4	67	107.6	1075.8
20.0	68	107.8	1077.9
20.6	69	108.0	1080.1
21.1	70	108.2	1082.2
21.7	71	108.4	1084.4
22.2	72	108.7	1086.6
22.8	73	108.9	1088.7
23.3	74	109.1	1090.9
23.9	75	109.3	1093.0
24.4	76	109.5	1095.2
25.0	77	109.7	1097.3
25.6	78	109.9	1099.5
26.1	79	110.2	1101.6
26.7	80	110.4	1103.8
27.2	81	110.6	1106.0
27.8	82	110.8	1108.1
28.3	83	111.0	1110.3
28.9	84	111.2	1112.4
29.4	85	111.5	1114.6
30.0	86	111.7	1116.7
30.6	87	111.9	1118.9
31.1	88	112.1	1121.0
31.7	89	112.3	1123.2
32.2	90	112.5	1125.3
32.8	91	112.7	1127.5
33.3	92	113.0	1129.6
33.9	93	113.2	1131.8
34.4	94	113.4	1133.9
35.0	95	113.6	1136.1
35.6	96	113.8	1138.2
36.1	97	114.0	1140.4
36.7	98	114.3	1142.5
37.2	99	114.5	1144.7
37.8	100	114.7	1146.8
38.3	101	114.9	1149.0
38.9	102	115.1	1151.1
39.4	103	115.3	1153.2
40.0	104	115.5	1155.4
40.6	105	115.8	1157.5

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
41.1	106	116.0	1159.7
41.7	107	116.2	1161.8
42.2	108	116.4	1164.0
42.8	109	116.6	1166.1
43.3	110	116.8	1168.3
43.9	111	117.0	1170.4
44.4	112	117.3	1172.5
45.0	113	117.5	1174.7
45.6	114	117.7	1176.8
46.1	115	117.90	1178.97
46.7	116	118.11	1181.11
47.2	117	118.33	1183.25
47.8	118	118.54	1185.39
48.3	119	118.75	1187.53
48.9	120	118.97	1189.67
49.4	121	119.18	1191.81
50.0	122	119.40	1193.95
50.6	123	119.61	1196.09
51.1	124	119.82	1198.23
51.7	125	120.04	1200.37
52.2	126	120.25	1202.50
52.8	127	120.46	1204.64
53.3	128	120.68	1206.78
53.9	129	120.89	1208.91
54.4	130	121.11	1211.05
55.0	131	121.32	1213.19
55.6	132	121.53	1215.32
56.1	133	121.75	1217.46
56.7	134	121.96	1219.59
57.2	135	122.17	1221.73
57.8	136	122.39	1223.86
58.3	137	122.60	1225.99
58.9	138	122.81	1228.13
59.4	139	123.03	1230.26
60.0	140	123.24	1232.39
60.6	141	123.45	1234.52
61.1	142	123.67	1236.66
61.7	143	123.88	1238.79

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
62.2	144	124.09	1240.92
62.8	145	124.31	1243.05
63.3	146	124.52	1245.18
63.9	147	124.73	1247.31
64.4	148	124.94	1249.44
65.0	149	125.16	1251.57
65.6	150	125.37	1253.70
66.1	151	125.58	1255.83
66.7	152	125.80	1257.96
67.2	153	126.01	1260.08
67.8	154	126.22	1262.21
68.3	155	126.43	1264.34
68.9	156	126.65	1266.47
69.4	157	126.86	1268.59
70.0	158	127.07	1270.72
70.6	159	127.28	1272.84
71.1	160	127.50	1274.97
71.7	161	127.71	1277.09
72.2	162	127.92	1279.22
72.8	163	128.13	1281.34
73.3	164	128.3	1283.5
73.9	165	128.6	1285.6
74.4	166	128.8	1287.7
75.0	167	129.0	1289.8
75.6	168	129.2	1292.0
76.7	170	129.6	1296.2
77.2	171	129.8	1298.3
77.8	172	130.0	1300.4
78.3	173	130.3	1302.6
78.9	174	130.5	1304.7
79.4	175	130.7	1306.8
80.0	176	130.9	1308.9
80.6	177	131.1	1311.0
81.1	178	131.3	1313.2
81.7	179	131.5	1315.3
82.2	180	131.7	1317.4
82.8	181	132.0	1319.5
83.3	182	132.2	1321.6

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
83.9	183	132.4	1323.8
84.4	184	132.6	1325.9
85.0	185	132.8	1328.0
85.6	186	133.0	1330.1
86.1	187	133.2	1332.2
86.7	188	133.4	1334.3
87.2	189	133.6	1336.5
87.8	190	133.9	1338.6
88.3	191	134.1	1340.7
88.9	192	134.3	1342.8
89.4	193	134.5	1344.9
90.0	194	134.7	1347.0
90.6	195	134.9	1349.1
91.1	196	135.1	1351.2
91.7	197	135.3	1353.4
92.2	198	135.5	1355.5
92.8	199	135.8	1357.6
93.3	200	136.0	1359.7
93.9	201	136.2	1361.8
94.4	202	136.4	1363.9
95.0	203	136.6	1366.0
95.6	204	136.8	1368.1
96.1	205	137.0	1370.2
96.7	206	137.2	1372.4
97.2	207	137.4	1374.5
97.8	208	137.7	1376.6
98.3	209	137.9	1378.7
98.9	210	138.1	1380.8
99.4	211	138.3	1382.9
100.0	212	138.5	1385.0
100.6	213	138.7	1387.1
101.1	214	138.92	1389.21
101.7	215	139.13	1391.32
102.2	216	139.34	1393.42
102.8	217	139.55	1395.53
103.3	218	139.76	1397.63
103.9	219	139.97	1399.74
104.4	220	140.18	1401.84
105.0	221	140.39	1403.95

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
105.6	222	140.60	1406.05
106.1	223	140.82	1408.15
106.7	224	141.03	1410.25
107.2	225	141.24	1412.36
107.8	226	141.45	1414.46
108.3	227	141.66	1416.56
108.9	228	141.87	1418.66
109.4	229	142.08	1420.76
110.0	230	142.29	1422.86
110.6	231	142.50	1424.96
111.1	232	142.71	1427.06
111.7	233	142.92	1429.16
112.2	234	143.13	1431.26
112.8	235	143.34	1433.36
113.3	236	143.55	1435.46
113.9	237	143.76	1437.55
114.4	238	143.97	1439.65
115.0	239	144.17	1441.75
115.6	240	144.38	1443.85
116.1	241	144.59	1445.94
116.7	242	144.80	1448.04
117.2	243	145.01	1450.13
117.8	244	145.22	1452.23
118.3	245	145.43	1454.32
118.9	246	145.64	1456.42
119.4	247	145.85	1458.51
120.0	248	146.06	1460.61
120.6	249	146.27	1462.70
121.1	250	146.48	1464.79
121.7	251	146.69	1466.89
122.2	252	146.90	1468.98
122.8	253	147.11	1471.07
123.3	254	147.32	1473.16
123.9	255	147.53	1475.26
124.4	256	147.73	1477.35
125.0	257	147.94	1479.44
125.6	258	148.15	1481.53
126.1	259	148.36	1483.62
126.7	260	148.57	1485.71

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
127.2	261	148.78	1487.80
127.8	262	148.99	1489.89
128.3	263	149.2	1492.0
128.9	264	149.4	1494.1
129.4	265	149.6	1496.1
130.0	266	149.8	1498.2
130.6	267	150.0	1500.3
131.1	268	150.2	1502.4
131.7	269	150.4	1504.5
132.2	270	150.7	1506.6
132.8	271	150.9	1508.7
133.3	272	151.1	1510.8
133.9	273	151.3	1512.8
134.4	274	151.5	1514.9
135.0	275	151.7	1517.0
135.6	276	151.9	1519.1
136.1	277	152.1	1521.2
136.7	278	152.3	1523.3
137.2	279	152.5	1525.3
137.8	280	152.7	1527.4
138.3	281	153.0	1529.5
138.9	282	153.2	1531.6
139.4	283	153.4	1533.7
140.0	284	153.6	1535.8
140.6	285	153.8	1537.8
141.1	286	154.0	1539.9
141.7	287	154.2	1542.0
142.2	288	154.4	1544.1
142.8	289	154.6	1546.2
143.3	290	154.8	1548.2
143.9	291	155.0	1550.3
144.4	292	155.2	1552.4
145.0	293	155.4	1554.5
145.6	294	155.7	1556.5
146.1	295	155.9	1558.6
146.7	296	156.1	1560.7
147.2	297	156.3	1562.8
147.8	298	156.5	1564.8

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
148.3	299	156.7	1566.9
148.9	300	156.9	1569.0
149.4	301	157.1	1571.1
150.0	302	157.3	1573.1
150.6	303	157.5	1575.2
151.1	304	157.7	1577.3
151.7	305	157.9	1579.4
152.2	306	158.1	1581.4
152.8	307	158.4	1583.5
153.3	308	158.6	1585.6
153.9	309	158.8	1587.7
154.4	310	159.0	1589.7
155.0	311	159.2	1591.8
155.6	312	159.4	1593.9
156.1	313	159.6	1595.9
156.7	314	159.8	1598.0
157.2	315	160.0	1600.1
157.8	316	160.2	1602.2
158.3	317	160.4	1604.2
158.9	318	160.6	1606.3
159.4	319	160.8	1608.4
160.0	320	161.0	1610.4
160.6	321	161.2	1612.5
161.1	322	161.5	1614.6
161.7	323	161.7	1616.6
162.2	324	161.9	1618.7
162.8	325	162.1	1620.8
163.3	326	162.3	1622.8
163.9	327	162.5	1624.9
164.4	328	162.7	1627.0
165.0	329	162.9	1629.0
165.6	330	163.1	1631.1
166.1	331	163.3	1633.2
166.7	332	163.5	1635.2
167.2	333	163.7	1637.3
167.8	334	163.9	1639.3
168.3	335	164.1	1641.4
168.9	336	164.3	1643.5

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
169.4	337	164.6	1645.5
170.0	338	164.8	1647.6
170.6	339	165.0	1649.7
171.1	340	165.2	1651.7
171.7	341	165.4	1653.8
172.2	342	165.6	1655.8
172.8	343	165.8	1657.9
173.3	344	166.0	1660.0
173.9	345	166.2	1662.0
174.4	346	166.4	1664.1
175.0	347	166.6	1666.1
175.6	348	166.8	1668.2
176.1	349	167.0	1670.3
176.7	350	167.2	1672.3
177.2	351	167.4	1674.4
177.8	352	167.6	1676.4
178.3	353	167.8	1678.5
178.9	354	168.1	1680.5
179.4	355	168.3	1682.6
180.0	356	168.5	1684.6
180.6	357	168.7	1686.7
181.1	358	168.9	1688.8
181.7	359	169.1	1690.8
182.2	360	169.3	1692.9
182.8	361	169.5	1694.9
183.3	362	169.7	1697.0
183.9	363	169.9	1699.0
184.4	364	170.1	1701.1
185.0	365	170.3	1703.1
185.6	366	170.5	1705.2
186.1	367	170.7	1707.2
186.7	368	170.9	1709.3
187.2	369	171.1	1711.3
187.8	370	171.3	1713.4
188.3	371	171.5	1715.4
188.9	372	171.7	1717.5
189.4	373	172.0	1719.5
190.0	374	172.2	1721.6
190.6	375	172.4	1723.6

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
191.1	376	172.6	1725.7
191.7	377	172.8	1727.7
192.2	378	173.0	1729.8
192.8	379	173.2	1731.8
193.3	380	173.4	1733.9
193.9	381	173.6	1735.9
194.4	382	173.8	1738.0
195.0	383	174.0	1740.0
195.6	384	174.2	1742.0
196.1	385	174.4	1744.1
196.7	386	174.6	1746.1
197.2	387	174.8	1748.2
197.8	388	175.0	1750.2
198.3	389	175.2	1752.3
198.9	390	175.4	1754.3
199.4	391	175.6	1756.4
200.0	392	175.8	1758.4
200.6	393	176.0	1760.4
201.1	394	176.2	1762.5
201.7	395	176.5	1764.5
202.2	396	176.7	1766.6
202.8	397	176.9	1768.6
203.3	398	177.1	1770.6
203.9	399	177.3	1772.7
204.4	400	177.5	1774.7
205.0	401	177.7	1776.8
205.6	402	177.9	1778.8
206.1	403	178.1	1780.8
206.7	404	178.3	1782.9
207.2	405	178.5	1784.9
207.8	406	178.7	1787.0
208.3	407	178.9	1789.0
208.9	408	179.1	1791.0
209.4	409	179.3	1793.1
210.00	410	179.5	1795.1
210.56	411	179.7	1797.1
211.11	412	179.9	1799.2
211.67	413	180.1	1801.2
212.22	414	180.3	1803.2

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
212.78	415	180.5	1805.3
213.33	416	180.7	1807.3
213.89	417	180.9	1809.3
214.44	418	181.1	1811.4
215.00	419	181.3	1813.4
215.56	420	181.5	1815.4
216.11	421	181.7	1817.5
216.67	422	182.0	1819.5
217.22	423	182.2	1821.5
217.78	424	182.4	1823.6
218.33	425	182.6	1825.6
218.89	426	182.8	1827.6
219.44	427	183.0	1829.7
220.00	428	183.2	1831.7
220.56	429	183.4	1833.7
221.11	430	183.6	1835.7
221.67	431	183.8	1837.8
222.22	432	184.0	1839.8
222.78	433	184.2	1841.8
223.33	434	184.4	1843.9
223.89	435	184.6	1845.9
224.44	436	184.8	1847.9
225.00	437	185.0	1849.9
225.56	438	185.2	1852.0
226.11	439	185.4	1854.0
226.67	440	185.6	1856.0
227.22	441	185.8	1858.0
227.78	442	186.0	1860.1
228.33	443	186.2	1862.1
228.89	444	186.4	1864.1
229.44	445	186.6	1866.1
230.00	446	186.8	1868.2
230.56	447	187.0	1870.2
231.11	448	187.2	1872.2
231.67	449	187.4	1874.2
232.22	450	187.6	1876.2
232.78	451	187.8	1878.3
233.33	452	188.0	1880.3

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
233.89	453	188.2	1882.3
234.44	454	188.4	1884.3
235.00	455	188.6	1886.3
235.56	456	188.8	1888.4
236.11	457	189.0	1890.4
236.67	458	189.2	1892.4
237.2	459	189.4	1894.4
237.8	460	189.6	1896.4
238.3	461	189.8	1898.5
238.9	462	190.0	1900.5
239.4	463	190.2	1902.5
240.0	464	190.5	1904.5
240.6	465	190.7	1906.5
241.1	466	190.9	1908.5
241.7	467	191.1	1910.6
242.2	468	191.3	1912.6
242.8	469	191.5	1914.6
243.3	470	191.7	1916.6
243.9	471	191.9	1918.6
244.4	472	192.1	1920.6
245.0	473	192.3	1922.6
245.6	474	192.5	1924.7
246.1	475	192.7	1926.7
246.7	476	192.9	1928.7
247.2	477	193.1	1930.7
247.8	478	193.3	1932.7
248.3	479	193.5	1934.7
248.9	480	193.7	1936.7
249.4	481	193.9	1938.7
250.0	482	194.1	1940.7
250.6	483	194.3	1942.8
251.1	484	194.5	1944.8
251.7	485	194.7	1946.8
252.2	486	194.9	1948.8
252.8	487	195.1	1950.8
253.3	488	195.3	1952.8
253.9	489	195.5	1954.8
254.4	490	195.7	1956.8

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
255.0	491	195.9	1958.8
255.6	492	196.1	1960.8
256.1	493	196.3	1962.8
256.7	494	196.5	1964.8
257.2	495	196.7	1966.8

Temp* (°C)	Temp (°F)	Resistance (100 Ohms)	Resistance (1000 Ohms)
257.8	496	196.9	1968.8
258.3	497	197.1	1970.9
258.9	498	197.3	1972.9
259.4	499	197.5	1974.9
260.0	500	197.7	1976.9

*Temperature coefficients: 100 Ohm: 0.0385 Ohm/ °C; 1000 Ohm: 3.85 Ohm/ °C.

Appendix D: Transmitter Tables (PV Input and mA Output)

Table D1. 40 to 140 °F temperature transmitter process variable input and transmitter mA output.

Temp	Output	Temp	Output	Temp	Output	Temp	Output
(°F)	(mA)	66	8.16	93	12.48	120	16.80
40	4.00	67	8.32	94	12.64	121	16.96
41	4.16	68	8.48	95	12.80	122	17.12
42	4.32	69	8.64	96	12.96	123	17.28
43	4.48	70	8.80	97	13.12	124	17.44
44	4.64	71	8.96	98	13.28	125	17.60
45	4.80	72	9.12	99	13.44	126	17.76
46	4.96	73	9.28	100	13.60	127	17.92
47	5.12	74	9.44	101	13.76	128	18.08
48	5.28	75	9.60	102	13.92	129	18.24
49	5.44	76	9.76	103	14.08	130	18.40
50	5.60	77	9.92	104	14.24	131	18.56
51	5.76	78	10.08	105	14.40	132	18.72
52	5.92	79	10.24	106	14.56	133	18.88
53	6.08	80	10.40	107	14.72	134	19.04
54	6.24	81	10.56	108	14.88	135	19.20
55	6.40	82	10.72	109	15.04	136	19.36
56	6.56	83	10.88	110	15.20	137	19.52
57	6.72	84	11.04	111	15.36	138	19.68
58	6.88	85	11.20	112	15.52	139	19.84
59	7.04	86	11.36	113	15.68	140	20.00
60	7.20	87	11.52	114	15.84		
61	7.36	88	11.68	115	16.00		
62	7.52	89	11.84	116	16.16		
63	7.68	90	12.00	117	16.32		
64	7.84	91	12.16	118	16.48		
65	8.00	92	12.32	119	16.64		

Table D2. –30 to 130 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
-30	4.00
-29	4.10
-28	4.20
-27	4.30
-26	4.40
-25	4.50
-24	4.60
-23	4.70
-22	4.80
-21	4.90
-20	5.00
-19	5.10
-18	5.20
-17	5.30
-16	5.40
-15	5.50
-14	5.60
-13	5.70
-12	5.80
-11	5.90
-10	6.00
-9	6.10
-8	6.20
-7	6.30
-6	6.40
-5	6.50
-4	6.60
-3	6.70
-2	6.80
-1	6.90
0	7.00
1	7.10
2	7.20
3	7.30
4	7.40
5	7.50
6	7.60
7	7.70
8	7.80
9	7.90
10	8.00
11	8.10
12	8.20
13	8.30
14	8.40
15	8.50
16	8.60
17	8.70
18	8.80
19	8.90
20	9.00
21	9.10
22	9.20
23	9.30
24	9.40
25	9.50
26	9.60
27	9.70
28	9.80
29	9.90
30	10.00
31	10.10
32	10.20
33	10.30
34	10.40
35	10.50
36	10.60
37	10.70
38	10.80
39	10.90
40	11.00
41	11.10
42	11.20
43	11.30
44	11.40
45	11.50
46	11.60
47	11.70
48	11.80
49	11.90
50	12.00
51	12.10
52	12.20
53	12.30
54	12.40
55	12.50
56	12.60
57	12.70
58	12.80
59	12.90
60	13.00
61	13.10
62	13.20
63	13.30
64	13.40
65	13.50
66	13.60
67	13.70
68	13.80
69	13.90
70	14.00
71	14.10
72	14.20
73	14.30
74	14.40
75	14.50
76	14.60
77	14.70
78	14.80
79	14.90
80	15.00
81	15.10
82	15.20
83	15.30
84	15.40
85	15.50
86	15.60
87	15.70
88	15.80
89	15.90
90	16.00
91	16.10
92	16.20
93	16.30
94	16.40
95	16.50
96	16.60
97	16.70
98	16.80
99	16.90
100	17.00
101	17.10
102	17.20
103	17.30
104	17.40
105	17.50
106	17.60
107	17.70
108	17.80
109	17.90
110	18.00
111	18.10
112	18.20
113	18.30
114	18.40
115	18.50
116	18.60
117	18.70
118	18.80
119	18.90
120	19.00
121	19.10
122	19.20
123	19.30
124	19.40
125	19.50
126	19.60
127	19.70
128	19.80
129	19.90
130	20.00

Table D3. 50 to 85°F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
50	4.00
51	4.56
52	4.91
53	5.37
54	5.83
55	6.29
56	6.74
57	7.20
58	7.66
59	8.11
60	8.57
61	9.03
62	9.49
63	9.94
64	10.40
65	10.86
66	11.31
67	11.77
68	12.23
69	12.69
70	13.14
71	13.60
72	14.06
73	14.51
74	14.97
75	15.43
76	15.89
77	16.34
78	16.80
79	17.26
80	17.71
81	18.17
82	18.63
83	19.09
84	19.54
85	20.00

Table D4. -30 to 130 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
-30	4.00
-29	4.10
-28	4.20
-27	4.30
-26	4.40
-25	4.50
-24	4.60
-23	4.70
-22	4.80
-21	4.90
-20	5.00
-19	5.10
-18	5.20
-17	5.30
-16	5.40
-15	5.50
-14	5.60
-13	5.70
-12	5.80
-11	5.90
-10	6.00
-9	6.10
-8	6.20
-7	6.30
-6	6.40
-5	6.50
-4	6.60
-3	6.70
-2	6.80
-1	6.90
0	7.00
1	7.10
2	7.20
3	7.30
4	7.40
5	7.50
6	7.60
7	7.70
8	7.80
9	7.90
10	8.00
11	8.10
12	8.20
13	8.30
14	8.40
15	8.50
16	8.60
17	8.70
18	8.80
19	8.90
20	9.00
21	9.10
22	9.20
23	9.30
24	9.40
25	9.50
26	9.60
27	9.70
28	9.80
29	9.90
30	10.00
31	10.10
32	10.20
33	10.30
34	10.40
35	10.50
36	10.60
37	10.70
38	10.80
39	10.90
40	11.00
41	11.10
42	11.20
43	11.30
44	11.40
45	11.50
46	11.60
47	11.70
48	11.80
49	11.90
50	12.00
51	12.10
52	12.20
53	12.30
54	12.40
55	12.50
56	12.60
57	12.70

Temp (°F)	Output (mA)
58	12.80
59	12.90
60	13.00
61	13.10
62	13.20
63	13.30
64	13.40
65	13.50
66	13.60
67	13.70
68	13.80
69	13.90
70	14.00
71	14.10
72	14.20
73	14.30
74	14.40
75	14.50
76	14.60

Temp (°F)	Output (mA)
77	14.70
78	14.80
79	14.90
80	15.00
81	15.10
82	15.20
83	15.30
84	15.40
85	15.50
86	15.60
87	15.70
88	15.80
89	15.90
90	16.00
91	16.10
92	16.20
93	16.30
94	16.40
95	16.50

Temp (°F)	Output (mA)
96	16.60
97	16.70
98	16.80
99	16.90
100	17.00
101	17.10
102	17.20
103	17.30
104	17.40
105	17.50
106	17.60
107	17.70
108	17.80
109	17.90
110	18.00
111	18.10
112	18.20
113	18.30
114	18.40

Temp (°F)	Output (mA)
115	18.50
116	18.60
117	18.70
118	18.80
119	18.90
120	19.00
121	19.10
122	19.20
123	19.30
124	19.40
125	19.50
126	19.60
127	19.70
128	19.80
129	19.90
130	20.00

Table D5. 50 to 85 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
50	4.00
51	4.56
52	4.91
53	5.37
54	5.83
55	6.29
56	6.74
57	7.20
58	7.66

Temp (°F)	Output (mA)
59	8.11
60	8.57
61	9.03
62	9.49
63	9.94
64	10.40
65	10.86
66	11.31
67	11.77

Temp (°F)	Output (mA)
68	12.23
69	12.69
70	13.14
71	13.60
72	14.06
73	14.51
74	14.97
75	15.43
76	15.89

Temp (°F)	Output (mA)
77	16.34
78	16.80
79	17.26
80	17.71
81	18.17
82	18.63
83	19.09
84	19.54
85	20.00

Table D6. 30 to 130 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)	Temp (°F)	Output (mA)	Temp (°F)	Output (mA)	Temp (°F)	Output (mA)
30	4.00	57	8.32	84	12.64	111	16.96
31	4.16	58	8.48	85	12.80	112	17.12
32	4.32	59	8.64	86	12.96	113	17.28
33	4.48	60	8.80	87	13.12	114	17.44
34	4.64	61	8.96	88	13.28	115	17.60
35	4.80	62	9.12	89	13.44	116	17.76
36	4.96	63	9.28	90	13.60	117	17.92
37	5.12	64	9.44	91	13.76	118	18.08
38	5.28	65	9.60	92	13.92	119	18.24
39	5.44	66	9.76	93	14.08	120	18.40
40	5.60	67	9.92	94	14.24	121	18.56
41	5.76	68	10.08	95	14.40	122	18.72
42	5.92	69	10.24	96	14.56	123	18.88
43	6.08	70	10.40	97	14.72	124	19.04
44	6.24	71	10.56	98	14.88	125	19.20
45	6.40	72	10.72	99	15.04	126	19.36
46	6.56	73	10.88	100	15.20	127	19.52
47	6.72	74	11.04	101	15.36	128	19.68
48	6.88	75	11.20	102	15.52	129	19.84
49	7.04	76	11.36	103	15.68	130	20.00
50	7.20	77	11.52	104	15.84		
51	7.36	78	11.68	105	16.00		
52	7.52	79	11.84	106	16.16		
53	7.68	80	12.00	107	16.32		
54	7.84	81	12.16	108	16.48		
55	8.00	82	12.32	109	16.64		
56	8.16	83	12.48	110	16.80		

Table D7. 200 to 500 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
200	4.00
205	4.27
210	4.53
215	4.80
220	5.07
225	5.33
230	5.60
235	5.87
240	6.13
245	6.40
250	6.67
255	6.93
260	7.20
265	7.47
270	7.73
275	8.00
280	8.27
285	8.53
290	8.80
295	9.07
300	9.33
305	9.60
310	9.87
315	10.13
320	10.40
325	10.67
330	10.93
335	11.20
340	11.47
345	11.73
350	12.00
355	12.27
360	12.53
365	12.80
370	13.07
375	13.33
380	13.60
385	13.87
390	14.13
395	14.40
400	14.67
405	14.93
410	15.20
415	15.47
420	15.73
425	16.00
430	16.26
435	16.53
440	16.80
445	17.07
450	17.33
455	17.60
460	17.87
465	18.13
470	18.40
475	18.67
480	18.93
485	19.20
490	19.47
495	19.73
500	20.00

Table D8. 30 to 240 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)	Temp (°F)	Output (mA)	Temp (°F)	Output (mA)	Temp (°F)	Output (mA)
30	4.00	86	8.27	142	12.53	198	16.80
32	4.15	88	8.42	144	12.69	200	16.95
34	4.30	90	8.57	146	12.84	202	17.10
36	4.46	92	8.72	148	12.99	204	17.26
38	4.61	94	8.88	150	13.14	206	17.41
40	4.76	96	9.03	152	13.30	208	17.56
42	4.91	98	9.18	154	13.45	210	17.71
44	5.07	100	9.33	156	13.60	212	17.87
46	5.22	102	9.49	158	13.75	214	18.02
48	5.37	104	9.64	160	13.90	216	18.17
50	5.52	106	9.79	162	14.06	218	18.32
52	5.68	108	9.94	164	14.21	220	18.48
54	5.83	110	10.10	166	14.36	222	18.63
56	5.98	112	10.25	168	14.51	224	18.78
58	6.13	114	10.40	170	14.67	226	18.93
60	6.29	116	10.55	172	14.82	228	19.09
62	6.44	118	10.70	174	14.97	230	19.24
64	6.59	120	10.86	176	15.12	232	19.39
66	6.74	122	11.01	178	15.28	234	19.54
68	6.90	124	11.16	180	15.43	236	19.70
70	7.05	126	11.31	182	15.58	238	19.85
72	7.20	128	11.47	184	15.73	240	20.00
74	7.35	130	11.62	186	15.89		
76	7.50	132	11.77	188	16.04		
78	7.66	134	11.92	190	16.19		
80	7.81	136	12.08	192	16.34		
82	7.96	138	12.23	194	16.50		
84	8.11	140	12.38	196	16.65		

Table D9. 40 to 240 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
40	4.00
42	4.16
44	4.32
46	4.48
48	4.64
50	4.80
52	4.96
54	5.12
56	5.28
58	5.44
60	5.60
62	5.76
64	5.92
66	6.08
68	6.24
70	6.40
72	6.56
74	6.72
76	6.88
78	7.04
80	7.20
82	7.36
84	7.52
86	7.68
88	7.84
90	8.00
92	8.16
94	8.32
96	8.48
98	8.64
100	8.80
102	8.96
104	9.12
106	9.28
108	9.44
110	9.60
112	9.76
114	9.92
116	10.08
118	10.24
120	10.40
122	10.56
124	10.72
126	10.88
128	11.04
130	11.20
132	11.36
134	11.52
136	11.68
138	11.84
140	12.00
142	12.16
144	12.32
146	12.48
148	12.64
150	12.80
152	12.96
154	13.12
156	13.28
158	13.44
160	13.60
162	13.76
164	13.92
166	14.08
168	14.24
170	14.40
172	14.56
174	14.72
176	14.88
178	15.04
180	15.20
182	15.36
184	15.52
186	15.68
188	15.84
190	16.00
192	16.16
194	16.32
196	16.48
198	16.64
200	16.80
202	16.96
204	17.12
206	17.28
208	17.44
210	17.60
212	17.76
214	17.92
216	18.08
218	18.24
220	18.40
222	18.56
224	18.72
226	18.88
228	19.04
230	19.20
232	19.36
234	19.52
236	19.68
238	19.84
240	20.00

Table D10. 100 to 250 °F temperature transmitter process variable input and transmitter mA output.

Temp (°F)	Output (mA)
100	4.00
101	4.11
102	4.21
103	4.32
104	4.43
105	4.53
106	4.64
107	4.75
108	4.85
109	4.96
110	5.07
111	5.17
112	5.28
113	5.39
114	5.49
115	5.60
116	5.71
117	5.81
118	5.92
119	6.03
120	6.13
121	6.24
122	6.35
123	6.45
124	6.56
125	6.67
126	6.77
127	6.88
128	6.99
129	7.09
130	7.20
131	7.31
132	7.41
133	7.52
134	7.63
135	7.73
136	7.84
137	7.95
138	8.05
139	8.16
140	8.27
141	8.37
142	8.48
143	8.59
144	8.69
145	8.80
146	8.91
147	9.01
148	9.12
149	9.23
150	9.33
151	9.44
152	9.55
153	9.65
154	9.76
155	9.87
156	9.97
157	10.08
158	10.19
159	10.29
160	10.40
161	10.51
162	10.61
163	10.72
164	10.83
165	10.93
166	11.04
167	11.15
168	11.25
169	11.36
170	11.47
171	11.57
172	11.68
173	11.79
174	11.89
175	12.00
176	12.11
177	12.21
178	12.32
179	12.43
180	12.53
181	12.64
182	12.75
183	12.85
184	12.96
185	13.07
186	13.17
187	13.28
188	13.39
189	13.49
190	13.60
191	13.71
192	13.81
193	13.92
194	14.03
195	14.13
196	14.24
197	14.35
198	14.45
199	14.56
200	14.67
201	14.77
202	14.88
203	14.99
204	15.09
205	15.20
206	15.31
207	15.41
208	15.52
209	15.63
210	15.73
211	15.84
212	15.95
213	16.05
214	16.16
215	16.27
216	16.37
217	16.48
218	16.59
219	16.69
220	16.80
221	16.91
222	17.01
223	17.12
224	17.23
225	17.33
226	17.44
227	17.55
228	17.65
229	17.76
230	17.87
231	17.97
232	18.08
233	18.19
234	18.29
235	18.40
236	18.51
237	18.61
238	18.72
239	18.83
240	18.93
241	19.04
242	19.15
243	19.25
244	19.36
245	19.47
246	19.57
247	19.68
248	19.79
249	19.89
250	20.00

Table D11. 0 to 100 %RH transmitter process variable input and transmitter mA output.

RH (%RH)	Output (mA)	RH (%RH)	Output (mA)	RH (%RH)	Output (mA)	RH (%RH)	Output (mA)
0	4.00	26	8.16	52	12.32	77	16.32
1	4.16	27	8.32	53	12.48	78	16.48
2	4.32	28	8.48	54	12.64	79	16.64
3	4.48	29	8.64	55	12.80	80	16.80
4	4.64	30	8.80	56	12.96	81	16.96
5	4.80	31	8.96	57	13.12	82	17.12
6	4.96	32	9.12	58	13.28	83	17.28
7	5.12	33	9.28	59	13.44	84	17.44
8	5.28	34	9.44	60	13.60	85	17.60
9	5.44	35	9.60	61	13.76	86	17.76
10	5.60	36	9.76	62	13.92	87	17.92
11	5.76	37	9.92	63	14.08	88	18.08
12	5.92	38	10.08	64	14.24	89	18.24
13	6.08	39	10.24	65	14.40	90	18.40
14	6.24	40	10.40	66	14.56	91	18.56
15	6.40	41	10.56	67	14.72	92	18.72
16	6.56	42	10.72	68	14.88	93	18.88
17	6.72	43	10.88	69	15.04	94	19.04
18	6.88	44	11.04	70	15.20	95	19.20
19	7.04	45	11.20	71	15.36	96	19.36
20	7.20	46	11.36	72	15.52	97	19.52
21	7.36	47	11.52	73	15.68	98	19.68
22	7.52	48	11.68	74	15.84	99	19.84
23	7.68	49	11.84	75	16.00	100	20.00
24	7.84	50	12.00	76	16.16		
25	8.00	51	12.16				

Table D12. 0 to 2.0 IWC differential pressure transmitter process variable input and transmitter mA output.

Pressure (iwc)	Output (mA)	Pressure (iwc)	Output (mA)	Pressure (iwc)	Output (mA)	Pressure (iwc)	Output (mA)
0.0	4.00	0.6	8.80	1.2	13.60	1.8	18.40
0.1	4.80	0.7	9.60	1.3	14.40	1.9	19.20
0.2	5.60	0.8	10.40	1.4	15.20	2.0	20.00
0.3	6.40	0.9	11.20	1.5	16.00		
0.4	7.20	1.0	12.00	1.6	16.80		
0.5	8.00	1.1	12.80	1.7	17.60		

Appendix E: Controller Tables (VDC/mA Input and SLDC PV Display)

1. Read volts across controller input terminals.
2. See tables below to convert volts to milliamps (mA).
3. See tables below to convert volts or mA to temperature.

Table E1. Volt or mA conversion to Temperature for Honeywell, Powers and Yokogawa Controllers (250 OHM PV or CPA Input).

V (volts)	I (mA)	Temperature (°F)			
		Sensor Span (-30 to 130 °F)	Sensor Span (100 to 250 °F)	Sensor Span (200 to 500 °F)	Sensor Span (30 to 240 °F)
1.0	4.0	-30.0	100.0	200.0	30.0
1.1	4.4	-26.0	103.8	207.5	35.3
1.2	4.8	-22.0	107.5	215.0	40.5
1.3	5.2	-18.0	111.3	222.5	45.8
1.4	5.6	-14.0	115.0	230.0	51.0
1.5	6.0	-10.0	118.8	237.5	56.3
1.6	6.4	-6.0	122.5	245.0	61.5
1.7	6.8	-2.0	126.3	252.5	66.8
1.8	7.2	2.0	130.0	260.0	72.0
1.9	7.6	6.0	133.8	267.5	77.3
2.0	8.0	10.0	137.5	275.0	82.5
2.1	8.4	14.0	141.3	282.5	87.8
2.2	8.8	18.0	145.0	290.0	93.0
2.3	9.2	22.0	148.8	297.5	98.3
2.4	9.6	26.0	152.5	305.0	103.5
2.5	10.0	30.0	156.3	312.5	108.8
2.6	10.4	34.0	160.0	320.0	114.0
2.7	10.8	38.0	163.8	327.5	119.3
2.8	11.2	42.0	167.5	335.0	124.5
2.9	11.6	46.0	171.3	342.5	129.8
3.0	12.0	50.0	175.0	350.0	135.0
3.1	12.4	54.0	178.8	357.5	140.3
3.2	12.8	58.0	182.5	365.0	145.5
3.3	13.2	62.0	186.3	372.5	150.8
3.4	13.6	66.0	190.0	380.0	156.0
3.5	14.0	70.0	193.8	387.5	161.3

V (volts)	I (mA)	Temperature (°F)			
		Sensor Span (-30 to 130 °F)	Sensor Span (100 to 250 °F)	Sensor Span (200 to 500 °F)	Sensor Span (30 to 240 °F)
3.6	14.4	74.0	197.5	395.0	166.5
3.7	14.8	78.0	201.3	402.5	171.8
3.8	15.2	82.0	205.0	410.0	177.0
3.9	15.6	86.0	208.8	417.5	182.3
4.0	16.0	90.0	212.5	425.0	187.5
4.1	16.4	94.0	216.3	432.5	192.8
4.2	16.8	98.0	220.0	440.0	198.0
4.3	17.2	102.0	223.8	447.5	203.3
4.4	17.6	106.0	227.5	455.0	208.5
4.5	18.0	110.0	231.3	462.5	213.8
4.6	18.4	114.0	235.0	470.0	219.0
4.7	18.8	118.0	238.8	477.5	224.3
4.8	19.2	122.0	242.5	485.0	229.5
4.9	19.6	126.0	246.3	492.5	234.8
5.0	20.0	130.0	250.0	500.0	240.0

Equations used to make this table:

Temperature (°F) = Low end of span + [(XmA - 4mA)/16mA] x (High end of span - Low end of span)

where:

X = current that is determined by using this table to convert measured volts to mA

V (volts) = Measured at controller PV or CPA input

R (ohms) = 250 ohms (resistor inside controller for PV input and CPA input)

I (mA) = (measured volts / 250 ohms) x 1000

Table E2. Volt or mA conversion to Temperature for Honeywell, Powers and Yokogawa Controllers (250 OHM PV or CPA Input)

V (volts)	I (mA)	Temperature (°F)			
		Sensor Span (30 to 100 °F)	Sensor Span (30 to 130 °F)	Sensor Span (50 to 85 °F)	Sensor Span (40 to 140 °F)
1.0	4.0	30.0	30.0	50.0	40.0
1.1	4.4	31.8	32.5	50.9	42.5
1.2	4.8	33.5	35.0	51.8	45.0
1.3	5.2	35.3	37.5	52.6	47.5
1.4	5.6	37.0	40.0	53.5	50.0
1.5	6.0	38.8	42.5	54.4	52.5
1.6	6.4	40.5	45.0	55.3	55.0
1.7	6.8	42.3	47.5	56.1	57.5
1.8	7.2	44.0	50.0	57.0	60.0
1.9	7.6	45.8	52.5	57.9	62.5

V (volts)	I (mA)	Temperature (°F) Sensor Span (30 to 100 °F)	Sensor Span (30 to 130 °F)	Sensor Span (50 to 85 °F)	Sensor Span (40 to 140 °F)
2.0	8.0	47.5	55.0	58.8	65.0
2.1	8.4	49.3	57.5	59.6	67.5
2.2	8.8	51.0	60.0	60.5	70.0
2.3	9.2	52.8	62.5	61.4	72.5
2.4	9.6	54.5	65.0	62.3	75.0
2.5	10.0	56.3	67.5	63.1	77.5
2.6	10.4	58.0	70.0	64.0	80.0
2.7	10.8	59.8	72.5	64.9	82.5
2.8	11.2	61.5	75.0	65.8	85.0
2.9	11.6	63.3	77.5	66.6	87.5
3.0	12.0	65.0	80.0	67.5	90.0
3.1	12.4	66.8	82.5	68.4	92.5
3.2	12.8	68.5	85.0	69.3	95.0
3.3	13.2	70.3	87.5	70.1	97.5
3.4	13.6	72.0	90.0	71.0	100.0
3.5	14.0	73.8	92.5	71.9	102.5
3.6	14.4	75.5	95.0	72.8	105.0
3.7	14.8	77.3	97.5	73.6	107.5
3.8	15.2	79.0	100.0	74.5	110.0
3.9	15.6	80.8	102.5	75.4	112.5
4.0	16.0	82.5	105.0	76.3	115.0
4.1	16.4	84.3	107.5	77.1	117.5
4.2	16.8	86.0	110.0	78.0	120.0
4.3	17.2	87.8	112.5	78.9	122.5
4.4	17.6	89.5	115.0	79.8	125.0
4.5	18.0	91.3	117.5	80.6	127.5
4.6	18.4	93.0	120.0	81.5	130.0
4.7	18.8	94.8	122.5	82.4	132.5
4.8	19.2	96.5	125.0	83.3	135.0
4.9	19.6	98.3	127.5	84.1	137.5
5.0	20.0	100.0	130.0	85.0	140.0

Equations used to make this table:

Temperature (°F) = Low end of span + [(XmA - 4mA)/16mA] x (High end of span - Low end of span)

X = current that is determined by using this table to convert measured volts to mA

V (volts) = Measured at controller PV or CPA input

R (ohms) = 250 ohms (resistor inside controller for PV input and CPA input)

I (mA) = (measured volts / 250 ohms) x 1000

Table E3. Volt or mA Conversion to temperature for BASYS SD-1000 (100 OHM PV or CPA input).

V (volts)	I (mA)	Temperature (°F) Sensor Span (-30 to 130 °F)	Sensor Span (100 to 250 °F)	Sensor Span (200 to 500 °F)	Sensor Span (30 to 240 °F)
0.40	4.0	-30.0	100.0	200.0	30.0
0.44	4.4	-26.0	103.8	207.5	35.3
0.48	4.8	-22.0	107.5	215.0	40.5
0.52	5.2	-18.0	111.3	222.5	45.8
0.56	5.6	-14.0	115.0	230.0	51.0
0.60	6.0	-10.0	118.8	237.5	56.3
0.64	6.4	-6.0	122.5	245.0	61.5
0.68	6.8	-2.0	126.3	252.5	66.8
0.72	7.2	2.0	130.0	260.0	72.0
0.76	7.6	6.0	133.8	267.5	77.3
0.80	8.0	10.0	137.5	275.0	82.5
0.84	8.4	14.0	141.3	282.5	87.8
0.88	8.8	18.0	145.0	290.0	93.0
0.92	9.2	22.0	148.8	297.5	98.3
0.96	9.6	26.0	152.5	305.0	103.5
1.00	10.0	30.0	156.3	312.5	108.8
1.04	10.4	34.0	160.0	320.0	114.0
1.08	10.8	38.0	163.8	327.5	119.3
1.12	11.2	42.0	167.5	335.0	124.5
1.16	11.6	46.0	171.3	342.5	129.8
1.20	12.0	50.0	175.0	350.0	135.0
1.24	12.4	54.0	178.8	357.5	140.3
1.28	12.8	58.0	182.5	365.0	145.5
1.32	13.2	62.0	186.3	372.5	150.8
1.36	13.6	66.0	190.0	380.0	156.0
1.40	14.0	70.0	193.8	387.5	161.3
1.44	14.4	74.0	197.5	395.0	166.5
1.48	14.8	78.0	201.3	402.5	171.8
1.52	15.2	82.0	205.0	410.0	177.0
1.56	15.6	86.0	208.8	417.5	182.3
1.60	16.0	90.0	212.5	425.0	187.5
1.64	16.4	94.0	216.3	432.5	192.8
1.68	16.8	98.0	220.0	440.0	198.0
1.72	17.2	102.0	223.8	447.5	203.3
1.76	17.6	106.0	227.5	455.0	208.5
1.80	18.0	110.0	231.3	462.5	213.8
1.84	18.4	114.0	235.0	470.0	219.0
1.88	18.8	118.0	238.8	477.5	224.3
1.92	19.2	122.0	242.5	485.0	229.5

V (volts)	I (mA)	Temperature (°F)			
		Sensor Span (-30 to 130 °F)	Sensor Span (100 to 250 °F)	Sensor Span (200 to 500 °F)	Sensor Span (30 to 240 °F)
1.96	19.6	126.0	246.3	492.5	234.8
2.00	20.0	130.0	250.0	500.0	240.0

Equations used to make this table:

Temperature (°F) = Low end of span + [(XmA - 4mA)/16mA] x (High end of span - Low end of span)

where:

X = current that is determined by using this table to convert measured volts to mA

V (volts) = Measured at controller PV or CPA input

R (ohms) = 100 ohms (resistor inside controller for PV input and CPA input)

(mA) = (measured volts / 100 ohms) x 1000

Table E4. Volt or mA conversion to temperature for BASYS SD-1000 (100 OHM PV or CPA input).

V (volts)	I (mA)	Temperature (°F)			
		Sensor Span (30 to 100 °F)	Sensor Span (30 to 130 °F)	Sensor Span (50 to 85 °F)	Sensor Span (40 to 140 °F)
0.40	4.0	30.0	30.0	50.0	40.0
0.44	4.4	31.8	32.5	50.9	42.5
0.48	4.8	33.5	35.0	51.8	45.0
0.52	5.2	35.3	37.5	52.6	47.5
0.56	5.6	37.0	40.0	53.5	50.0
0.60	6.0	38.8	42.5	54.4	52.5
0.64	6.4	40.5	45.0	55.3	55.0
0.68	6.8	42.3	47.5	56.1	57.5
0.72	7.2	44.0	50.0	57.0	60.0
0.76	7.6	45.8	52.5	57.9	62.5
0.80	8.0	47.5	55.0	58.8	65.0
0.84	8.4	49.3	57.5	59.6	67.5
0.88	8.8	51.0	60.0	60.5	70.0
0.92	9.2	52.8	62.5	61.4	72.5
0.96	9.6	54.5	65.0	62.3	75.0
1.00	10.0	56.3	67.5	63.1	77.5
1.04	10.4	58.0	70.0	64.0	80.0
1.08	10.8	59.8	72.5	64.9	82.5
1.12	11.2	61.5	75.0	65.8	85.0
1.16	11.6	63.3	77.5	66.6	87.5
1.20	12.0	65.0	80.0	67.5	90.0
1.24	12.4	66.8	82.5	68.4	92.5
1.28	12.8	68.5	85.0	69.3	95.0
1.32	13.2	70.3	87.5	70.1	97.5

V (volts)	I (mA)	Temperature (°F) Sensor Span (30 to 100 °F)	Sensor Span (30 to 130 °F)	Sensor Span (50 to 85 °F)	Sensor Span (40 to 140 °F)
1.36	13.6	72.0	90.0	71.0	100.0
1.40	14.0	73.8	92.5	71.9	102.5
1.44	14.4	75.5	95.0	72.8	105.0
1.48	14.8	77.3	97.5	73.6	107.5
1.52	15.2	79.0	100.0	74.5	110.0
1.56	15.6	80.8	102.5	75.4	112.5
1.60	16.0	82.5	105.0	76.3	115.0
1.64	16.4	84.3	107.5	77.1	117.5
1.68	16.8	86.0	110.0	78.0	120.0
1.72	17.2	87.8	112.5	78.9	122.5
1.76	17.6	89.5	115.0	79.8	125.0
1.80	18.0	91.3	117.5	80.6	127.5
1.84	18.4	93.0	120.0	81.5	130.0
1.88	18.8	94.8	122.5	82.4	132.5
1.92	19.2	96.5	125.0	83.3	135.0
1.96	19.6	98.3	127.5	84.1	137.5
2.00	20.0	100.0	130.0	85.0	140.0

Equations used to make this table:

Temperature (°F) = Low end of span + [(XmA - 4mA)/16mA] x (High end of span - Low end of span)

Where

X = current that is determined by using this table to convert measured volts to mA

(volts) = Measured at controller PV or CPA input

(ohms) = 100 ohms (resistor inside controller for PV input and CPA input)

(mA) = (measured volts / 100 ohms) x 1000

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14. ABSTRACT

Operation and maintenance (O&M) of heating, ventilating, and air-conditioning (HVAC) control systems can be a challenging task. To simplify the design, construction, and O&M of HVAC controls, the U.S. Army Corps of Engineers has developed standardized control system designs and hardware. This standardization increases the similarity of systems, reduces the stock of replacement parts, and allows mechanics to adapt to a uniform method for correcting performance problems. This manual is meant to apply to these standard systems; it describes how to interpret HVAC control system documentation, how to break the system down into control loops, and how to use that information to help troubleshoot and correct operational problems.

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